AERONAUTICAL ENGINEERING REVIEW

AUGUST 1950

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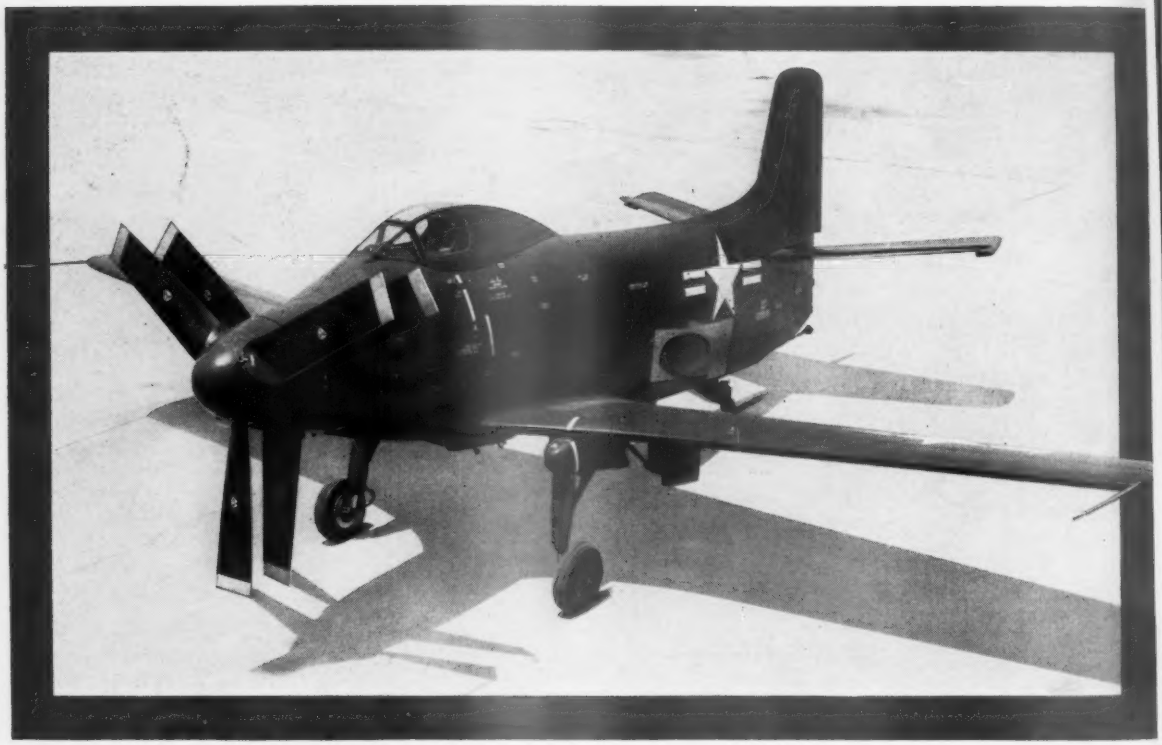

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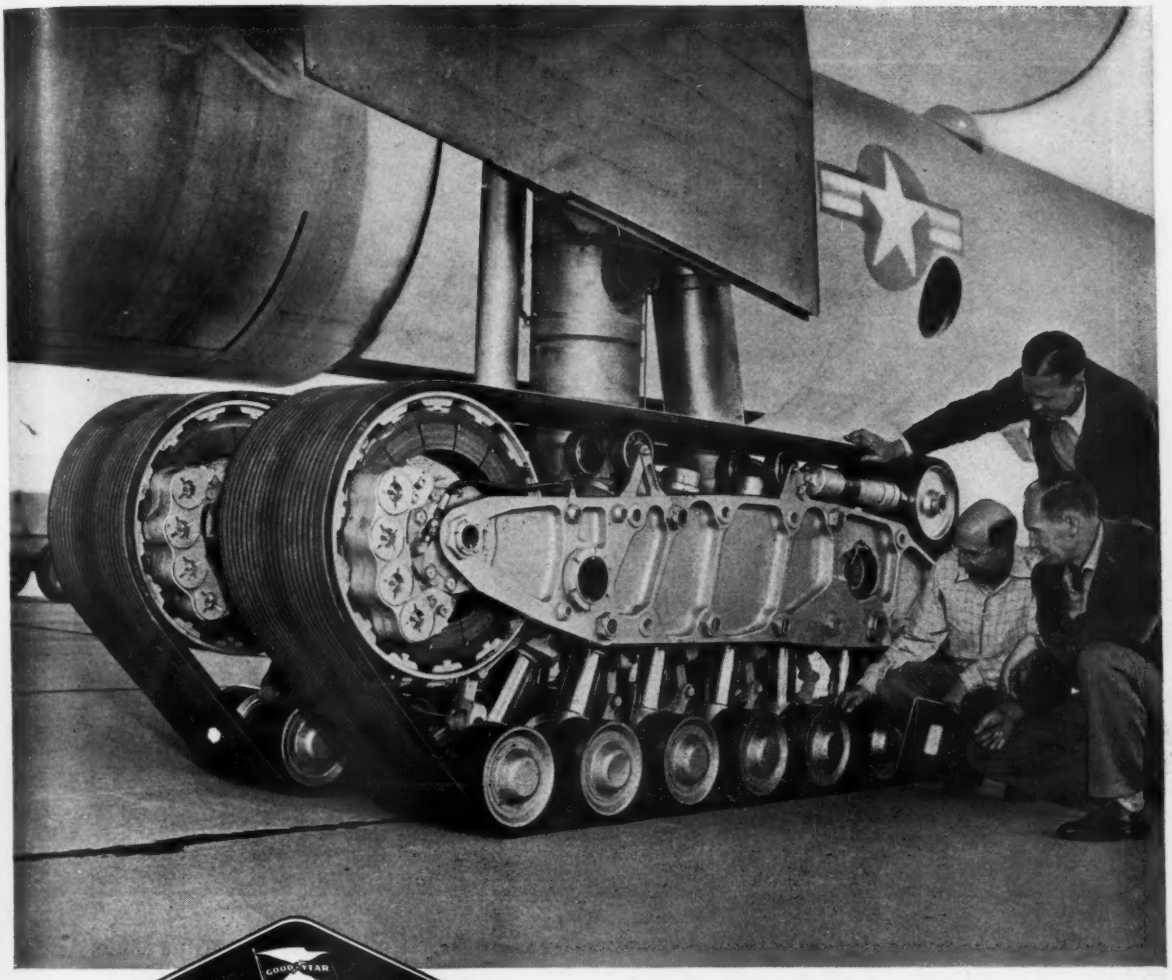

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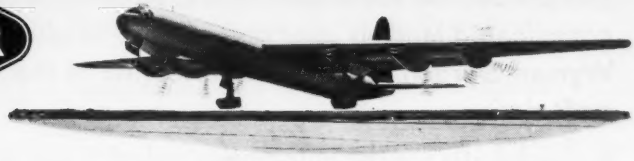

It makes the B-36 light on its feet

OPERATING a giant B-36 from landing strips not firm enough for its wheel loads is no longer a problem. Today one of these long-range bombers is making successful take-offs and landings on a new caterpillar-type track landing gear, designed jointly by Goodyear and Convair engineers. Out of its experience in building track gear for other planes, Goodyear developed endless rubber tracks, brakes and brake bogies required for safe handling of the world's largest bomber. This track gear gives the B-36 a "footprint" three times larger than conventional wheel gear—makes it light enough on its feet to use many additional runways. Goodyear leadership in landing gear design explains why more aircraft use Goodyear equipment than any other kind.

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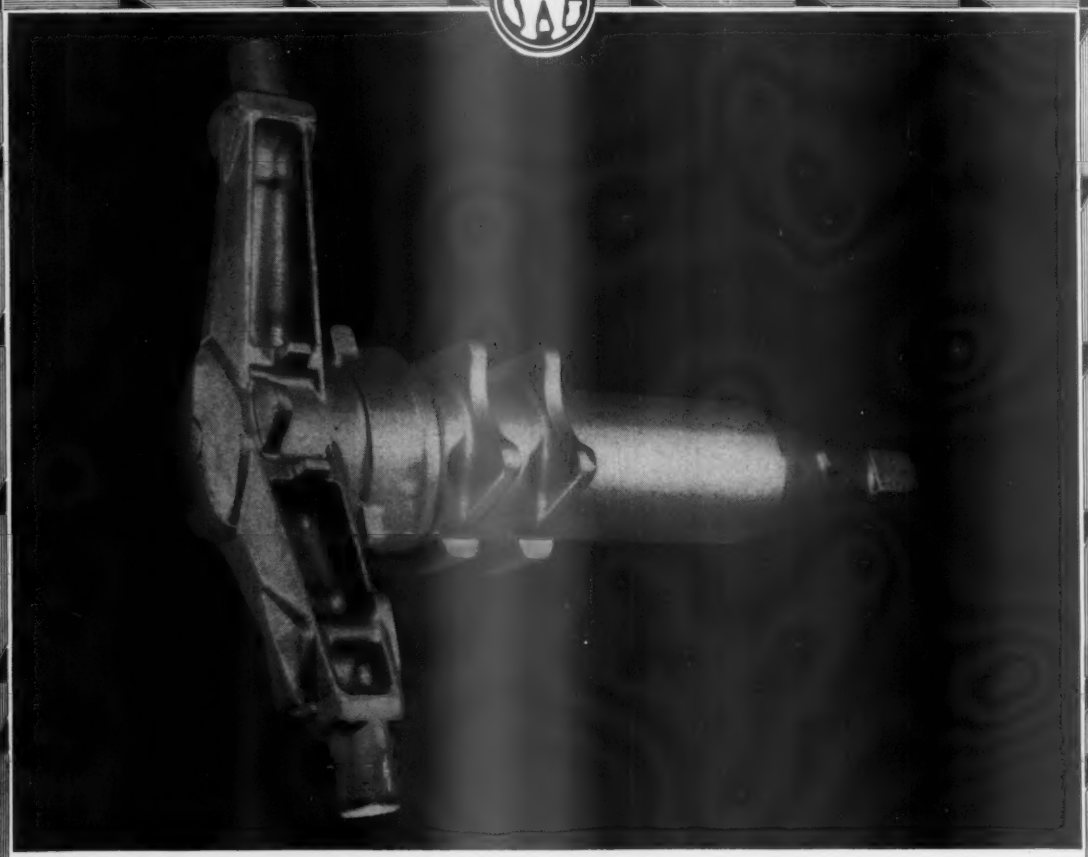

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Cover—Navy Grumman F9F-3 "Panther" carrier-based jet fighter.

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Robert R. Dexter
S. Paul Johnston

Business Manager
Joseph P. Ryan

Western Office
7660 Beverly Blvd., Los Angeles 36, Calif.

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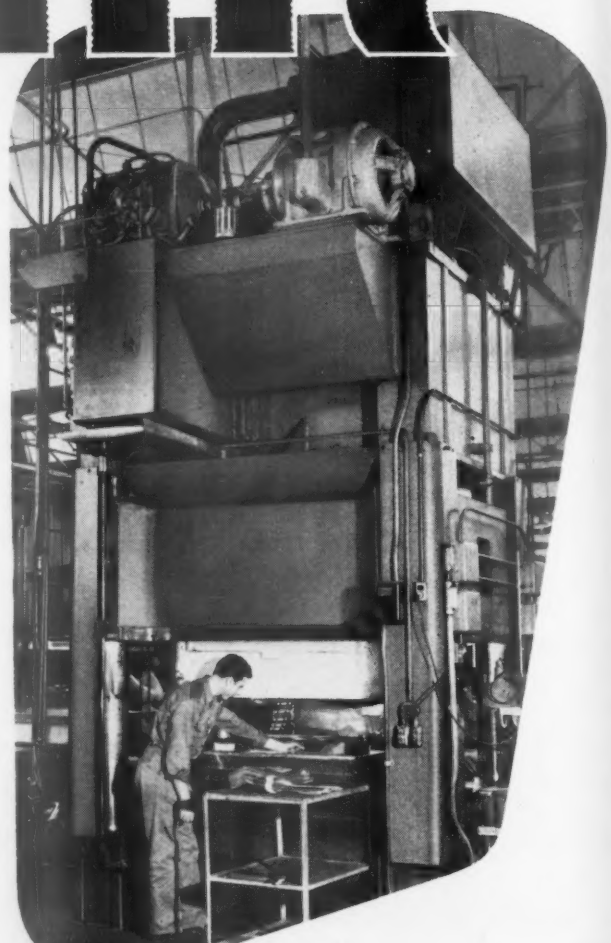

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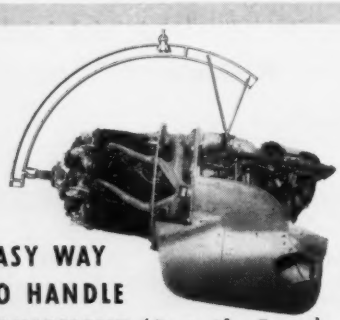

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I. A. S. News

A Record of People and Events of Interest to Institute Members

San Diego Building's First Year of Operation

San Diego's First Annual Aviation Award Banquet; Average of 25 Meetings Held Monthly; Library Facilities Growing

AN EVENT UNIQUE IN THE HISTORY of the I.A.S. occurred June 1 at San Diego and tied the aeronautical engineering profession of that aircraft center into an intimate new relationship with its community.

The occasion was San Diego's First Annual Aviation Award Banquet, with the Institute Section serving as the instrument of an overall civic committee to honor a local citizen for "The most outstanding contributions to the community of San Diego in the field of aviation during the year 1950."

LaMotte T. Cohu, President of Consolidated Vultee Aircraft Corporation, received the above citation in the Institute auditorium from Section Chairman Dwight H. Bennett. Principal address of the evening was given by Vice Adm. Calvin T. Durgin, U.S.N., Commander of the First Fleet.

Present at the banquet, in addition to top local aircraft industry people, was a large delegation of community leaders headed by the Mayor; the Chairman of County Supervisors; the President of the Chamber of Commerce; and high-ranking Air Force, Marine, and Coast Guard officers.

Thus, hand in hand with the community it serves, the new San Diego Section building of the Institute marked the close of its first year of operation. The civic award banquet will be repeated each June hereafter.

Since the building was dedicated by the incumbent National President, William A. M. Burden, on April 29, 1949, it has housed an average of 25 meetings monthly, mostly with food service. All organized groups in the sciences that contribute to aeronautics have been made welcome, and, in addition, the building has catered to unrelated groups and social affairs for the dual purpose of serving its community and helping to balance its operating budget.

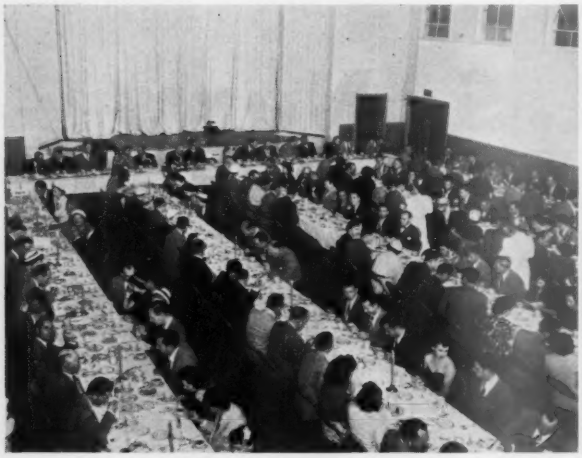
Attendance at these functions numbered several thousands aside from regular and special Institute meetings.

From the beginning, the Custodian has been Paul Herman. In recent months, Mr. Herman and his wife have, in addition, taken over the handling of nearly all food catering. Patron satisfaction with their service is best judged by the steadily rising demand for open dinner dates. On the day of the Award Banquet, the Hermans handled a luncheon for 350 guests while the dinner preparations were under way.

In Mr. Herman's absence, the building is in charge of Mrs. Gayl Mansfield, who serves as Secretary-Librarian. As a volunteer service, Mrs. Mansfield keeps the reading room open on those evenings when technical societies are using the building, and free library service is extended to members of such groups.

Donations of books and technical periodicals from both the New York and Los Angeles I.A.S. libraries have been received at San Diego, and the Section is carefully expending a fund contributed by the Fleet Foundation for addi-

Vice Adm. Calvin T. Durgin, U.S.N. *(left)*, shown with Mrs. LaMotte T. Cohu and Mr. Cohu, San Diego Civic Award recipient.



(Left) Part of the 260 leaders of San Diego's business and aviation activities who gathered for the Award Banquet in the auditorium of the I.A.S. San Diego Section Building on June 1. *(Right)* Paul Herman, Custodian of the San Diego Section Building, is shown here with Mrs. Herman preparing food for the San Diego First Annual Aviation Award Banquet.

tional standard reference works. During the year, Reuben H. Fleet made a further donation of a valuable oriental rug for the library.

Mr. Fleet, founder of Consolidated Aircraft Corporation (which later became Convair), while National President of the I.A.S. in 1944 conceived the idea of establishing Institute buildings at San Diego and Los Angeles and secured the support of industry heads to that end. The resulting beautiful facility on San Diego Harbor, with an auditorium seating 400 and complete library, kitchen, dining room, and office facilities, represents a cash investment of over $200,000 for the improvements alone.

It was thus especially appropriate to have Mr. and Mrs. Fleet present at the June 1 Award Banquet, where he again received the joint plaudits of a community and a national technical society, which are always eager to express their thanks to the "Major."

St. Louis Section Organized

The St. Louis Section of the I.A.S. was organized at a formal meeting held on June 6. Officers elected were: Chairman, Don R. Berlin; Vice-Chairman, David S. Lewis, Jr.; Secretary, Jack A. Durand; and Treasurer, Carl Wenzinger. Elected members of the Executive Board were: W. L. Wells, Niels C. Beck, Robert R. Osborn, and Dr. C. J. Kippenhan.

The organization of this I.A.S. Section has been primarily due to the efforts of J. S. McDonnell, President, McDonnell Aircraft Corporation; Dr. Lawrence E. Stout, Dean, Washington University; Niels C. Beck, Dean, Parks Air College, St. Louis University; and other local aviation leaders who through cooperative effort are striving to further the development of the St. Louis area as one of the major aviation centers of the Middle West. These efforts culminated in an I.A.S. preorganization meeting held in St. Louis on May 17, where the local I.A.S. members elected to form the St. Louis Section.

S. Paul Johnston, Director of the Institute, spoke at the preorganization meeting. Mr. Johnston, with the assistance of Robert R. Dexter, Secretary, outlined the structure of the I.A.S. organization and concluded with an enlightening discussion of the functions of the Research and Development Board of the Department of National Defense.

Chairman Berlin has an enviable record of achievements which began in the Aerodynamics Laboratory of the U.S. Army Air Corps, Dayton, Ohio, in 1920 and extended through Chief Draftsman of Douglas Aircraft, Chief Engineer at Northrop Aircraft, Director of Engineering at Curtiss Airplane and Motor Company in Buffalo, Director of Aircraft Development with Fisher Body Division of General Motors Corporation, and Director of Installation Engineering at Allison Division of General Motors, to his

Among those seated at the head table, obviously enjoying themselves, were *(left to right)*: Ernest G. Stout, A.F., I.A.S. Vice-President and Assistant to Chief Engineer, Consolidated Vultee Aircraft Corporation; James A. Robbins, Chairman of San Diego County Supervisors; Col. B. C. Batterton, U.S.M.C., Commanding Officer, Marine Air Group Twelve; Major Reuben H. Fleet, A.M., I.A.S. Past-President; Comdr. D. V. MacDiarmid, U.S.C.G., Assistant Chief of Staff, Eleventh Naval District; and James L. Straight, I.A.S. Assistant Director.

Don R. Berlin, Chairman of the newly formed St. Louis Section.

present position in 1947 as Executive Vice-President and Member of the Board of Directors, McDonnell Aircraft Corporation.

Equally outstanding are the backgrounds of Dave Lewis, Chief, Aerodynamics, McDonnell Aircraft Corporation; Jack Durand, Instructor, Parks Air College, St. Louis University; Carl Wenzinger, Chief Aerodynamics, Sverdrup and Parcel, St. Louis; Dr. C. J. Kippenhan, Dean of the Engineering School, Washington University; Niels Beck, Dean, Parks Air College; Willis Wells, President, George E. Wells, Inc.; and R. Osborn, Consultant, Helicopter Division, McDonnell Aircraft Corporation.

Mr. Berlin was introduced by Vernon Outman, Chief Technical Engineer at McDonnell, who served as chairman of the election. In his inaugural address, Mr. Berlin summarized the objectives of the local I.A.S. group, placing emphasis on the free exchange of ideas and the value of technical papers as an educational factor.

The meeting was concluded with a paper given by Dr. Kurt Hohenemser, of McDonnell, a world authority on helicopter aerodynamics. Dr. Hohenemser's paper, entitled "A Type of Lifting Rotor with Inherent Stability," summarized the principal features of various rotor systems. Stability characteristics of the rotors were demonstrated through the use of an actual working model. Slides were used to present the results of an analytical investigation, comparing the static and dynamic stability characteristics of the rotor systems. Dr. Hohenemser's lecture was followed by a period of enthusiastic discussion of the influence of the rotor system on overall stability of the helicopter.

VERNON OUTMAN and
ARTHUR LAMBERT

Lawrence Tech Student Wins Technical Paper Award

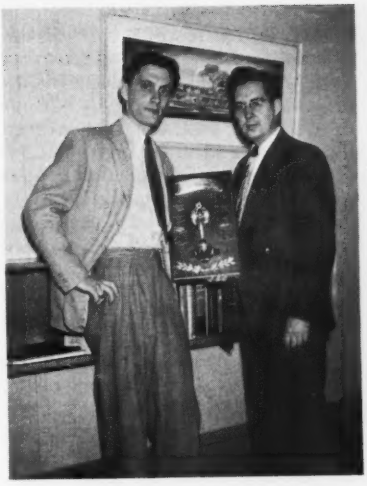
The "Third Annual Student Technical Paper Award" was presented to Thomas E. Campbell, Lawrence Institute of Technology, at a dinner held on April 28 at the Wayne University Student Center.

This was the third such competition to be sponsored by the I.A.S. Detroit Section and the first in which Lawrence Tech was a participant. The competition, in which one undergraduate student from each of the competing schools presents a paper on an aeronautical subject of his choice, is held annually among the University of Michigan, University of Detroit, Wayne University, and Lawrence Institute of Technology. The object of the competition is to encourage individual initiative, to improve the techniques of report writing and technical presentation, and to emphasize the importance of clear thinking and simple explanation in the presentation of engineering data. However, for any paper to qualify for entry in the interschool competition, it must first win an elimination contest held by each participating school.

The guest judges, appointed by the Detroit Section, were: Edward Hulburt, Vice-President and Chief Design Engineer, Continental Motors Corporation; David M. Borden, M.I.A.S., Consulting Engineer, Chrysler Corporation; and Dr. A. W. Bull, Director, Tire Development, United States Rubber Company.

▶ **Entrants**—Papers entered in the final contest were: "The Design and Construction of the 'Spirit of Lawrence Tech,'" by Thomas E. Campbell, of Lawrence Tech; "'Avicar'; a New Roadable Airplane," by George Hebges, of the University of Detroit; "A Study of a Ground Vehicle Propelled by Momentum Changes in Natural Air Masses," by University of Michigan's Jesse H. Nourse; and "Problems in the Development of a Miniature Pulse Jet Engine," by Paul H. Stahlhuth, of Wayne.

Thomas E. Campbell, who received a $75 cash prize and an appropriately engraved statuette, was, at the time of the presentation, a senior aeronautical engineering student and



Author and Designer: *Thomas E. Campbell (left), author of the winning student technical paper from Lawrence Institute of Technology, and George P. Martin, T.M.-I.A.S. (right), Department Head, Aeronautical Engineering, Lawrence Tech, and designer of the "Spirit of Lawrence Tech," hold the Student Branch award. This wall plaque, which rotates yearly among the participating schools, was presented this year to Lawrence Tech.*

A Lawrence Tech Product: *The "Spirit of Lawrence Tech" was built entirely by the students of the Lawrence Institute of Technology and was entered in the 1949 Goodyear race at Cleveland.*

Chairman of the I.A.S. Student Branch at Lawrence Tech. His association with the "Spirit of Lawrence Tech" dates from 1947 (when the design was first conceived by George P. Martin, T.M.I.A.S., Department Head, Aeronautical Engineering, Lawrence Tech) to its completion in 1949 and subsequent entry in the Goodyear race at Cleveland last year. The 'Spirit of Lawrence Tech" finished eighth in the consolation event.

▸ **Paper Presented**—In his paper, Mr. Campbell stated: "Since the 'Spirit of Lawrence Tech' is one of the first successful power airplanes intended to be entered in open racing competition and built by an American college, it has attracted considerable attention in the aviation field." Of the airplane itself, he said: "The 'Spirit' is of a twin-boom, pusher configuration, using a pod-type fuselage. The wing area is 74 sq.ft. and the wing span and length are each 20 ft. The 85-hp. Continental engine propels a gross weight of 750 lbs. The most unconventional aspect of the aircraft is the landing gear. Here the two fixed wheels are placed in tandem to each other, and both are partially enclosed in the keel section of the fuselage."

Mr. Campbell discussed the restrictions placed upon the preliminary design as a potential entry into the Goodyear race and by purely aerodynamic factors. "The pusher configuration," he said, "was favored primarily because it enabled the landing gear to be enclosed in the keel section, thus practically eliminating drag from the landing gear." Continuing, he stated that from a crude wooden mock-up "the major details of the pilot-seating arrangement, center section, torque box, and engine mount were worked out." The tail surfaces, booms, center section, and torque box were built for final assembly in that order; the outer wing panels and fuselage were constructed at the same time.

Under the headings, Empennage, Booms, Center Section, Outer Wing Panels, Fuselage, Control System, Cooling System, Static Testing, and Flight Testing, Mr. Campbell covered the details of construction of each member part. This included things such as the types of material used, problems encountered and their solutions, and methods of fabrication.

In concluding his report, Mr. Campbell pointed out that this project "did much to acquaint the students with aircraft construction techniques and familiarize them with the basic engineering principles involved in the design and construction of aircraft."

National Meetings Calendar

December 16	Wright Brothers Lecture, Washington, D.C.
Jan. 29–31, Feb. 1, 1951	Nineteenth Annual Meeting, New York

For details see page 64

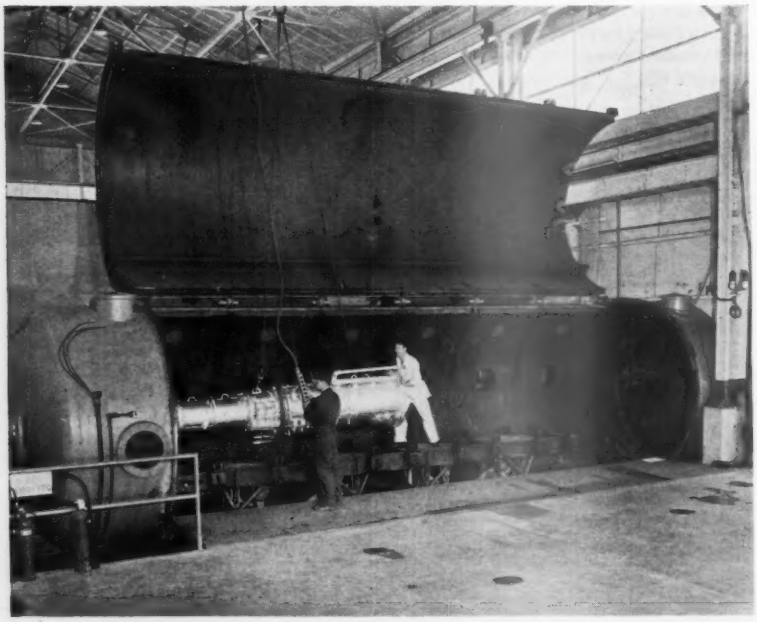
High-Altitude Test Chamber at Ordnance Aerophysics Laboratory

For the first time in America's missile research program, tests of large-scale ram-jet engines at simulated altitudes of approximately 20 miles above the earth and at speeds up to Mach 4 were begun last May in a newly completed test chamber at the Ordnance Aerophysics Laboratory, Daingerfield, Tex. The laboratory is operated for the Navy Bureau of Ordnance by Consolidated Vultee Aircraft Corporation, under the technical direction of the Applied Physics Laboratory of The Johns Hopkins University.

▸ **High-Altitude Tests**—The test chamber permits engineers to conduct tests up to altitudes of 100,000 ft. at four times the speed of sound with ram-jet engines as large as 48 in. in diameter. Laboratory testing of ram-jet engines at high altitudes and supersonic speeds produces data vital to the nation's guided-missile program and greatly reduces the number of flight tests required, thus saving both time and money.

▸ **Test Chamber**—The cylindrical test chamber is 10 ft. in diameter and 125 ft. in length, with a door in its side 30 ft. long through which ram-jet engines are installed for tests. A high-pressure air supply, coupled with a vacuum system for simulating high altitudes, enables engineers to conduct tests throughout the normal operating range of ram-jet engines. The vacuum system combines steam-jet ejectors with turboblowers to obtain maximum capacity from a steam supply of 270,000 lbs. per hour at a pressure of 400 lbs. per sq.in. By way of comparison, this quantity of steam would supply electricity for a city of 100,000 persons. A cooling system provides 30,000 gal. of water per min. to the barometric condensers between the ejectors and blowers and to the ram-jet exhaust cooling system.

▸ **Availability**—For 5 years the Ordnance Aerophysics Laboratory has played an important role in the nation's guided-missile program, operating three sea-level ram-jet test chambers and a supersonic wind tunnel capable of speeds up to 1,800 m.p.h. through a rectangular test sec-



New Test Chamber for Guided-Missile Project: *A large-scale ram-jet engine is being lowered into position for a test run in the newly constructed high-altitude test chamber at the Ordnance Aerophysics Laboratory, Daingerfield, Tex. Large-scale ram-jet engines may be tested here at simulated altitudes of approximately 20 miles above the earth and at speeds of Mach 4.*

tion measuring 19 by 27.5 in. While the Laboratory is the tool of a unique research and development team of 14 industrial organizations and eight universities associated with the Navy on the guided-missile program known as "Bumblebee," it is available to all branches of the service, as well as to approximately 60 industrial contractors, research organizations, and universities.

▸ **Accomplishments** — Achievements under this Navy-industry-university plan include the VT proximity fuse, the supersonic ram-jet engine, and the Aerobee rocket. The "Bumblebee" program was established within this overall plan in 1945, when the Navy set up a special guided-missile section in the Applied Physics Laboratory of The Johns Hopkins University, Silver Spring, Md.

Historical Branch Formed in Los Angeles

A number of Historical Associate members of the Los Angeles Section of the I.A.S. have organized a Historical Branch.

▸ **Inception**—The Branch, which had its initial meeting on March 3, is an outgrowth of the Aero Historical Society, which was formed early last summer by engineering personnel of North American Aviation, Inc. The purpose of both the predecessor organization and the new Historical Branch is to promote interest in, and arrange for, the preservation of aeronautical material of historical value.

John Sloan, Standard Engineer, North American, former president of the Aero Historical Society, was elected Chairmen of the Branch at the March 3 meeting. Committee chairmen appointed by Mr. Sloan included Lee Enich, of Manuel T. Fine Company, Photo Committee; and the following from North American Aviation: Eugene Clay, M.I.A.S., Engineer, Rules Committee; R. L. Bliss, Handbook Supervisor, Program Committee; Ralph B. Oakley, Aerophysics Laboratory, Publicity and Publications Committee; and George Lawlor, Artist, Exhibit Committee.

▸ **Exhibit**—The first activity of the Historical Branch consisted of an exhibit of photographs and models, held at the I.A.S. Western Headquarters in Los Angeles on March 25 and 26. Lee Enich loaned his collection of photographs of more than 2,000 airplanes, and Al Schmidt, Photographer for North American, supplied a number of recent enlargements. Models of current military and civilian aircraft were supplied by North American; Lockheed Aircraft Corporation; Douglas Aircraft Company, Inc.; Northrop Aircraft, Inc.; Bauman Aircraft of Van Nuys; and Dustin Carter. Don Dwiggins, *Los Angeles Daily News*, loaned a model of an aircraft that was granted a patent in 1889. Three hundred members and friends attended this exhibit.

Periodic meetings of general interest to all I.A.S. members are planned. Motion pictures of historical aviation events are to be shown, and speakers who can contribute information of the past decades of aviation both of local and national interest are being lined up for future meetings.

Gifts to the Institute Collections

W. A. M. Burden and Col. Edwin E. Aldrin added to their previous gifts with periodicals, and books and periodicals, respectively. The Eclipse-Pioneer Division, Bendix Aviation Corporation, through Miss Mildred M. Baker, gave British and American periodicals. Valuable technical reports were received from the Air Navigation Development Board, the Defense Research Laboratory of the University of Texas, the National Research Council of Canada, and the British Joint Services Mission.

Additional gifts were received from the Adel Precision Products Corporation; Aeronca Aircraft Corporation; Aeronautical Radio, Inc.; Air Transport Association; American Helicopter Corporation; Beech Aircraft Corporation; Bellanca Aircraft Corporation; Bendix Aviation Corporation; Boeing Airplane Company; Cessna Aircraft Corporation: Consolidated-Vultee Aircraft Corporation; Curtiss - Wright Corporation; Esso Standard Oil Company; Evans Research & Development Corporation; Applied Physics Labora-

(*Continued on page 87*)

Necrology

Count Jean de Chappedelaine

Count Jean de Chappedelaine, M.I.A.S., died on February 23 in Cheboygan, Mich., after a lingering illness.

▸ **Helicopter Research**—Count de Chappedelaine, who was a French representative to the United Nations on the International Civil Aviation Organization, did extensive research in the rotary-wing field under a subsidy of the French Air Ministry. At one time he was General Manager of the Société d'Étude des Aérogyres de Chappedelaine, and in the years before his death much of his time was devoted to the developing and building of a helicopter of his own design. In this regard, Count de Chappedelaine held United States and foreign helicopter patents.

▸ **U.S. Assignment**—Shortly after his being commissioned in 1940 as a Lieutenant, Reserve, in the French Air Force, he was sent to the United States with the French Air Commission and represented his government at Bell Aircraft Corporation and Curtiss-Wright Corporation. After a year in the Engineering Department of the latter concern, he was associated with the Army Aviation Division of the Netherlands Purchasing Commission.

▸ **Education**—Born in Le Mans, France, in 1893, he was graduated as a mechanical engineer from the University of Paris. He also attended the École Militaire d'Artillerie de Fontainebleau. He authored various papers that were published in French aeronautical magazines.

Count de Chappedelaine is survived by his wife, the former Vera Sangster, of Cheboygan, Mich.

Col. Gilbert Jerrold

Colonel Gilbert Jerrold, M.I.A.S., died last April 13. Funeral services were held in Washington, D.C., the following day.

▸ **French Government Service**—Colonel Jerrold, of the French Technical Air Corps, was Assistant Air Attaché and Chief of the Purchasing Mission for the French Air Force at the time of his death. Born in Paris in 1909, he was educated in both French and English schools. Entering the service of the French Air Ministry immediately after his graduation from the École Nationale Supérieure d'Aéronautique in Paris, his first assignment was Chief of the Power-Plant Installation Section of the Service Technique de l'Aéronautique.

▸ **Service in U.S.**—In 1939, he made his first official appearance in the United States with the French Air Mission as an expert on power-plant installations and air frames. The next year he was charged with the liquidation of all French contracts involving technical materials and products. During 1943–1945, he managed the Atelier Industriel de l'Air, Algiers, the most important of the French maintenance plants in Africa. In 1945, he became Technical Assistant to the French Air Attaché in the United States.

News of Members

▸ **Frank R. Brine,** H.A.I.A.S., has formed Frank R. Brine, Advertising, at 444 Madison Ave., New York, N.Y., for the servicing of general and industrial accounts. Mr. Brine was associated with The Babb Company, Inc., as Advertising Manager.

▸ **Captain P. W. S. Bulman,** M.I.A.S., Test Pilot, Hawker Aircraft, Limited, was awarded the British Silver Medal by the Royal Aeronautical Society for practical achievement in aeronautics.

▸ **Ralph S. Damon,** F.I.A.S., President, Trans World Airlines, Inc., has been elected a member of the Board of Directors, Commerce and Industry Association of New York, Inc.

▸ **Richard W. Darrow,** A.M.I.A.S., Director, Public Relations, The Glenn L. Martin Company, has been elected Chairman of the Public Relations Advisory Committee, Aircraft Industries Association.

▸ **Sir Geoffrey de Havilland,** H.F.I.A.S., Technical Director, The de Havilland Aircraft Company, England, was awarded the highest honor that can be conferred by the Royal Aeronautical Society, the Society's Gold Medal, given for work of an outstanding nature in aeronautics.

▸ **Dr. Wayne E. Kuhn,** M.I.A.S., Manager, Technical and Research Division, The Texas Company, was awarded, on May 24, the Second Honor Scroll of the New York Chapter of The American Institute of Chemists.

▸ **Paul W. Litchfield,** A.M.I.A.S., Chairman of the Board, Goodyear Tire & Rubber Company, was honored by Air Service Post No. 501, American Legion, for his 40 years of contribution to aviation. The ceremony took place at the Naval Air Station, Lakehurst, N.J., last May.

▸ **Owen Q. Niehaus,** T.M.I.A.S., Chief Test Pilot, Bell Aircraft Corporation, flew a helicopter, on May 15, over the Niagara River to assist in saving a woman clinging to a rock and ended up by being among those rescued from the river. While a rope was being tied to the immerged woman, the helicopter tipped sufficiently to allow one of its rotor blades to hit the water. The ship turned over, hurling Mr. Niehaus and Joseph A. Cannon, also of Bell Aircraft, into the Niagara. A second helicopter was dispatched to the scene and all were ultimately rescued. Mr. Niehaus was apparently none the worse for his unscheduled dipping.

▸ **Dean C. Smith,** M.I.A.S., Director of Contracts, Hughes Aircraft Company, a division of Hughes Tool Company, has been elected a Director of Lear, Inc.

Members on the Move

This new section has been instituted to give information on latest affiliations of I.A.S. Members. All members are urged to notify the News Editor of changes as soon as they occur.

Raymond C. Blaylock, A.F.I.A.S., Assistant Chief Engineer, Chance Vought Aircraft Division, United Aircraft Corporation. Formerly, Chief of Design, Chance Vought.

Dalton R. Buckingham, T.M.I.A.S., Mechanical Controls, Engineering Department, Canadair Limited. Formerly, Engineer, Department of Mechanical Engineering, National Research Council, Canada.

Laurance H. Cooper, A.M.I.A.S., Vice-President and General Manager, Pacific Airmotive Corporation, has taken an indefinite leave of absence on advice of his physician.

Captain Roy Jackson, U.S.N., M.I.A.S., Commanding Officer, U.S. Naval Air Rocket Test Station, Lake Denmark, Dover, N.J. Formerly, Overhaul and Repair Officer, N.A.S., Seattle.

Dr. Maurice Nelles, M.I.A.S., Professor of Research and Director, Engineering Experiment Station, The Pennsylvania State College. Formerly, Manager, Engineering and Research, Allan Hancock Foundation, University of Southern California.

Howard F. Rough, M.I.A.S., Civil Aviation Adviser, Department of State and C.A.A., Paris. Formerly, Assistant to the Administrator for Field Relations, C.A.A., Washington, D.C.

R. Dixon Speas, M.I.A.S., U.S. Representative for A. V. Roe Canada Limited. Formerly, Special Assistant to the President, American Airlines System.

Philip E. Spindell, M.I.A.S., Engineer, Piasecki Helicopter Corporation. Formerly, Project Engineer, Kellett Aircraft Corporation.

Charles E. Wittliff, T.M.I.A.S., Aeronautical Research Scientist, Gas Dynamics Branch, Langley Aeronautical Laboratory, N.A.C.A., Langley Air Force Base, Va. Formerly, Graduate Student and Teaching Fellow, Department of Aeronautical Engineering, University of Michigan.

APPOINTED

John Russell Clark, A.F.I.A.S., Assistant Chief Engineer, Chance Vought Aircraft Division, United Aircraft Corporation, formerly, Chief, Experimental Section, Chance Vought. Graduating from Massachusetts Institute of Technology in 1929 with a B.S. degree in aeronautical engineering, Clark joined United Aircraft Corporation in 1935. Since his appointment in 1948 as Experimental Chief, he has worked with Vought's newest airplane, the twin-jet F7U-1 Cutlass.

Attention Members!

All members of the Institute are invited to submit material concerning their activities for publication in the "News of Members" columns of the *Aeronautical Engineering Review*. Responsibility for new developments, awards or honors received, and appointments to new or additional positions are some of the items that your editors believe are of interest to other I.A.S. Members. A brief letter or postal card giving *exact* details will be sufficient. Photographs accompanying news items will be welcomed and will be used where practicable.

Items submitted will be considered on the basis of their timeliness and general interest. Correspondence should be addressed to the News Editor, *Aeronautical Engineering Review*, 2 East 64th Street, New York 21, N.Y.

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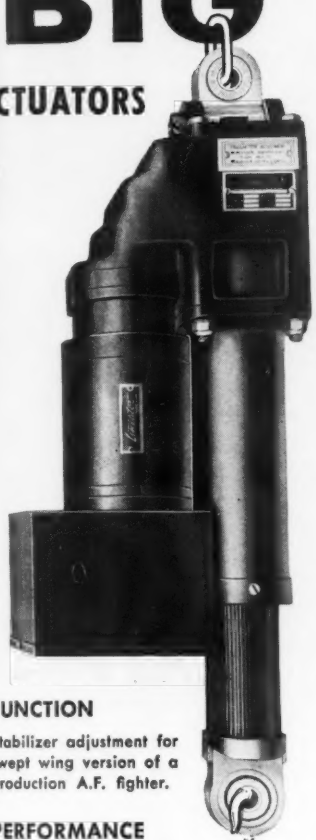

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Corporate Member News

• Contract . . . **Aerojet Engineering Corporation** has been awarded a U.S. Navy contract for Jato units in the amount of $440,000.

• New Offices . . . **Aeroproducts Division,** General Motors Corporation, has established offices at 200 Hill Bldg., 17th & I Sts., N.W., Washington, D.C., and at 317 Professional Bldg., 7046 Hollywood Blvd., Hollywood, Calif.

• Hose Line Assembly . . . **Aeroquip Corporation** has made available a Hose-Assembly Machine for large users of their hose lines. It will accommodate all types of standard Aeroquip fittings.

• Defunct Subsidiary. . . **Aluminum Company of America** has assumed the manufacturing activities of its now-defunct magnesium-fabricating subsidiary, American Magnesium Corporation.

• Host. . . **Bendix Products Division,** Bendix Aviation Corporation, played host on May 11 to 130 teachers of the South Bend, Ind., public and parochial schools.

• Flying-Boom Tankers . . . The first two production-type flying-boom aerial-refueling tankers have been completed by **Boeing Airplane Company.** The KB-29P, a modified version of the B-29, will be used for in-flight refueling of Boeing B-50's. The "boom" makes it possible to transfer fuel in the air at higher speeds, at higher altitudes, and at greater rates of flow than have been attainable with hose and reel systems through the use of its telescoping controllable tube, extending from the tail of the tanker plane to the socket on the receiver plane . . . A U.S.A.F. contract awarded to Boeing calls for the modification by June, 1951, of a B-47B to include the installation of four Allison J-35-A-23 engines at a cost of $4,122,427.

• Converter . . . An 8½-oz., 400-cycle converter, developed by **Brown Instrument Division,** Minneapolis-Honeywell Regulator Company, can be used with any system involving the conversion of low-power direct-voltage signals of the order of 100 microvolts to 400-cycle alternating voltages . . . A modified version of the Brown Radiamatic Pyrometer head, which is used with an ElectroniK potentiometer has been developed by Brown Instrument. The device is for measuring and controlling temperatures up to 7,000°F. in nuclear and atomic energy research and other projects.

• New Laboratory . . . **Chance Vought Aircraft Division,** United Aircraft Corporation, has built a fuel-test laboratory that will be used to study fuel-flow control problems occasioned by the many flow lines and several tanks in modern high-speed aircraft.

• First Flight . . . The XP5Y-1 flying boat, manufactured by **Consolidated Vultee Aircraft Corporation,** has completed its first test flight. It is powered by four Allison T-40's . . . Seven B-36's were returned to Convair for jet-pod modification . . . Consolidated Vultee is planning an air liner specifically designed to take full advantage of powerful turboprop engines.

(*Continued on page 76*)

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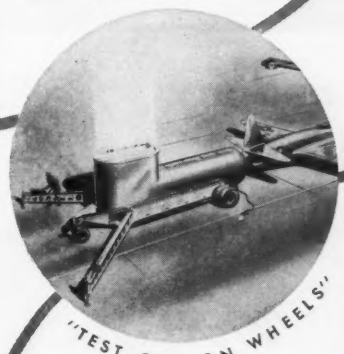

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3rd International Conference

I. A. S. - R. Ae. S.

LONDON • SEPTEMBER, 1951

Editorial

A Look Ahead

At the time of the Second International Aeronautical Conference with the British Royal Aeronautical Society, members of the Councils of both groups met jointly to lay down policy for future activities. It was the unanimous view that the results of the first two sessions (one in London in September, 1947; the other in New York in the Spring of 1949) warranted a continuation of the program. It was also agreed that meetings should be held on a 2-year cycle, alternating in locale between Great Britain and the United States. Thus, every fourth year, we (or the British) would be host to the Conference.

To some of us, the 1949 Conference seems but yesterday. Our calendars, however, remind us that over a year has already gone by since the last of our guests from overseas took off for home. Looking the other way along the time scale, September, 1951, the month selected for the Third Meeting, is already bearing down on us.

In recent weeks we have been in touch with the Officers and Council of the R.Ae.S., and detailed discussions concerning definite dates and matters relating to programs have already been undertaken. Although confirmation must come from the Councils on both sides, the probabilities are that joint technical sessions will be held in or near London in the week immediately following the Society of British Aircraft Constructors annual display at Farnborough. This will give our American delegates an opportunity to observe the latest current British aircraft at close range, and in the air, before settling down to conference matters.

As before, a program of visits to outstanding manufacturing and government establishments will be arranged. There will be unlimited opportunity, of course, to discuss matters of common interest with our "opposite numbers" in the U.K. And—to top it off—visitors from America will be exposed to a brand of hospitality that will be long remembered, as those of us who were in London in September, 1947, well know.

Within the next few months our programs will be completed. Announcement will be made shortly of arrangements for transportation and accommodation of the American delegates. Also invitations will go out to those who will be asked to contribute technical papers at the Conference.

The two conferences behind us have established high standards for technical papers presented. There is a growing feeling on both sides that the prestige attached to the reading of a paper at a Joint Conference is of the same order of magnitude as an invitation to present a Wilbur Wright Memorial Lecture in England or a Wright Brothers Lecture in America. We trust that all those who will be invited to present papers in London in the Fall of 1951 will share this view. Our papers must be of the highest caliber, both in content and in presentation. We should all exert ourselves to the utmost to make the Anglo-American Conferences of the R.Ae.S. and the I.A.S. of the maximum benefit to both countries and thus contribute to the stability of the peace of the world.

S. P. J.

Propeller Turbines in Transport Aircraft

W. C. KELLER*

Consolidated Vultee Aircraft Corporation

THE USE OF PROPELLER TURBINES in transport aircraft in this country has awaited the availability of a satisfactory domestically manufactured power plant. Such an engine is now potentially available, and the first installation will be a joint effort between Convair and General Motors to install an Allison 501-A2 engine in a Convair 240.

British progress in the use of propeller turbines is generally well known throughout the industry. To date, England has produced about six major models and has logged considerable flight hours with them in both military and transport air frames.

American history on propeller turbines has been one of fits and starts, directly proportional to military desire or ability to furnish development monies. The world's first propeller-turbine flight was made in an American airplane with an American power plant. The Convair XP-81 (Fig. 1), powered with a General Electric TG-100, flew in December, 1945. As anticipated, correlation of propeller and turbine controls constituted the major problem, a condition that is still existent. With development on the verge of yielding valuable data for continuing progress, financial support was withdrawn and American propeller-turbine development went into one of its several periods of hibernation. Ryan was later to install the TG-100 in the Navy Fireball with a parallel result.

After several more false starts in American propeller-turbine development, one engine emerged as being satisfactory for new design considerations. The Allison T-40 is the first engine that appears to have received (Fig. 2) the nod for full development. This engine has been designed into several military air frames that are now touching on the flight phase.

One of these projects (Fig. 3) is the Convair XP5Y-1, powered by four Allison T-40 units. This airplane has started its water taxi tests and is scheduled for flight at an early date.

Convair chose the T-40 power plants for the XP5Y because of the substantial weight-savings and the sizeable performance increase possible. The installation is exceptionally clean, with the power units completely buried within the wing contours. The combination of these power plants and a hydrodynamically new air frame opens a new era in water-borne aircraft.

In the course of developing the T-40, which is a dual turbine unit, a test engine was created consisting of one-half of the T-40. This test unit, designated the T-38, now appears ready to stand in its own right as the first logical contender for commercial application, for which it carries the designation Allison Model 501-A2 (Fig. 4).

Presented at the Fifth Annual Flight Propulsion Meeting, I.A.S., Cleveland, March 24, 1950.

* Project Engineer.

The Allison 501 propeller turbine consists of a turbine section and a propeller reduction gear housing, joined together by an interconnecting structure. The first engines installed will have the tubular structure designed for the test T-38, to be replaced by a cleaner, more compact, and more efficient interconnection on near-future versions. Mounting is to two points on the reduction gearbox and to one point on the compressor housing. Accessories are all located on the rear face of the gearbox, and turbine components are mounted on the underside of the compressor section. The propeller to be used is a four-bladed, Aeroproducts steel propeller of 13-ft. 6-in. diameter. Gearing is 12:5:1, giving a propeller speed of 1,146 r.p.m. for a turbine speed of 14,300 r.p.m.

The 501 is rated statically at 2,550 shaft hp. and 415-lb. thrust, with an equivalent shaft power at take-off speed of 2,750 hp. Dry weight of the engine is 1,225 lbs. for a weight per horsepower figure of 0.448. Work is well under way to increase substantially the power of this engine with negligible weight and space change.

To meet demands for improved economic and aerodynamic performance in commercial transport aircraft, a study was instigated of turbine-powered air-frame designs relative to air-line economics. In the light of the high development costs for completely new air frames necessary to exploit properly jet propulsion, the general economic structure of the air-frame manufacturing industry, and the lack of Federal subsidy for such development, it was concluded that adaptation of propeller turbines to existing air-frame designs would be the next most logical step. Higher powers and lower engine weights allow further saturation of current air-frame potential to yield economic and performance gains that are sure to find favor with air-line operators, provide the intermediate step toward long-range jet transports, and create a category of propeller-turbine transports for short and medium ranges which will continue on as an economically solid type.

The impetus for the installation of the Allison 501 engine in the Convair 240 evolved from a desire to offer the Air Force (Fig. 5) a higher performance for the military version, the T-29 Navigational Trainer. Besides giving the Air Force an airplane that would fulfill a definite military requirement for high-altitude, high-performance training of navigators and bombardiers, use by the Air Force of this engine would provide the initial production necessary to reduce its manufacturing costs and provide a service history. Although future commercial possibilities of transports powered with this turbine were outstandingly apparent from the start, it was realized that a military need

FIG. 1. XP-81.

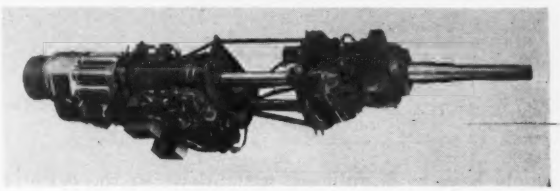

FIG. 2. Allison T-40.

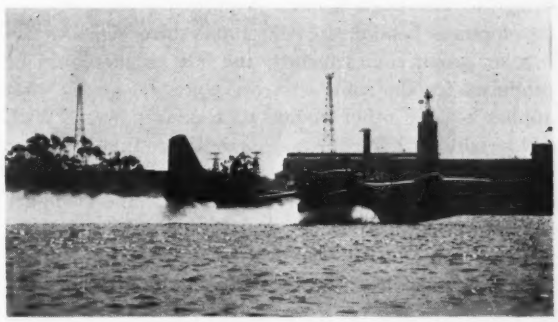

FIG. 3. XP5Y-1.

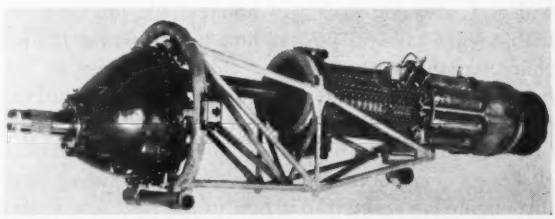

FIG. 4. General Motors, Allison 501–A2; 2,550 shaft hp. plus 415 lbs. jet thrust; 1,225 lbs. weight.

FIG. 5. T-29.

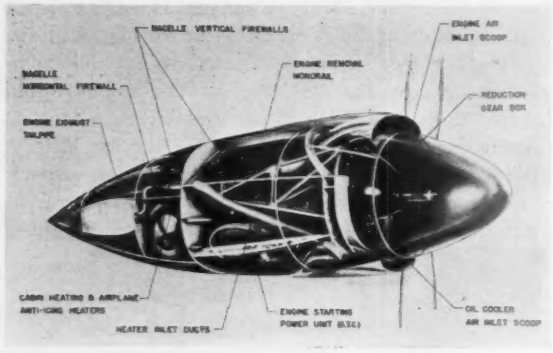

FIG. 6. General Motors installation; Allison 501-A2 propeller turbine in Convair 240.

would have to be fulfilled, without which the price of the turbine would remain out of reach of commercial operators. Every engine used in commercial transport design to date has a history of military acceptance and development behind it. Allison has stated that, with a regular production schedule, the 501 engine could be produced for the same cost per pound of engine that applies to any other engine of similar power. With low weight per horsepower, this indicates that propeller turbine first-costs will be lower than reciprocating engines or that, weight for weight, a turbine of higher horsepower can be purchased at the same price. Keep in mind that the 501 employs the same turbine as the T-40, so any military production on the latter engine favors the price on the former.

The installation of the Allison engine in the 240 does not present any serious air-frame problems and will give a weight-saving of about 1,400 lbs. (Fig. 6) with higher take-off powers and better power fall-off characteristics with altitude. Foresightedness in the basic design of the 240 allowed ample design margins for higher power-plant ratings so that the basic structure is unaffected. In this vein, it should be added that all design considerations are for the higher rating that this engine is expected to attain in the next few years. It has been contended that hot-day take-off performance causes turbines to suffer more than reciprocating engines, which is true. The net power available, however, is still higher than that of comparable reciprocating engines in the case of the 240. This loss can be minimized by water injection, which is under consideration now by Allison, to bring the percentage loss down close to that suffered by the reciprocating engines.

The 240 installation is straightforward. By laying the turbine and tailpipe over the wheel well and wing structure and by having the centerline of the propeller below the turbine axis, it is possible to maintain substantially the same thrust line as in current Convair-Liners. The identical fire-wall contour of the 240 is being maintained, as well as the basic nacelle lines aft of the fire-wall, modified only as necessary for the change in tailpipe. This design policy makes possible a future conversion of existing 240 aircraft through modification kits. The nacelle forward of the fire-wall is monocoque, with the 501 mounting directly to it. The engine has three mounting points, the front two, as noted, attaching to the monocoque and the third, at the compressor section, attaching to the fire-wall. Engine air is introduced through a scoop in the upper side of the nacelle and is ducted directly to the turbine. Turbine exhaust is directed into the tailpipe with an aspirating connection.

It was necessary to add combustion heaters for wing and tail anti-icing because of the low engine-heat rejection. There are two heaters in each nacelle, one on each side of the turbine section. Air for the heaters is supplied from the oil-cooler duct. Heater exhaust is aspirated into the tailpipe at the turbine exit.

Oil-cooler air is ducted directly to the cooler and then dumped overboard. The oil-cooling requirements are primarily for gearbox lubrication. Only about 30 per cent is required for the turbine.

The oil cooler is mounted above a larger centerline door in the bottom of the nacelle, through which the engine is readily accessible for maintenance. The floor of the turbine compartment is similarly hinged to afford service access. All fluid, electrical, and control lines are equipped with quick-disconnect fittings. Engine replacement is accomplished by removing the turbine-propeller assembly forward out of the nacelle and plugging in a replacement. A monorail is built into the nacelle along the top centerline to accommodate a roller equipped hanger attached to the engine for replacement purposes.

Starting is accomplished by compressed air furnished by an AiResearch gas-turbine compressor located in one nacelle, with a connection for an alternate ground source of air located in the same nacelle. Future starting considerations are expected to reduce materially the weight, cost, and bulky nature of the present gear.

Power-plant control equipment, developed for Allison by Aeroproducts, is primarily electronic. The cockpit unit is a single power lever for each turbine. Although control is indicated to be satisfactory, major development work still centers on this item. For test purposes, the first airplane will have an alternate means of separately controlling the propeller and turbine, in addition to the automatic features.

The power-lever angular travel is divided into two parts. The forward part controls the engine between operational idle and full power. The after segment, depending on selection, is either cut-off or the Beta control régime, which controls the propeller angle from just below low pitch forward to full reverse. This régime is used for starting and taxiing. As the idle speed of 13,500 r.p.m. is so close to the top speed of the turbine, taxi-control must be by means of blade pitch change rather than r.p.m. Entry into the Beta régime must be deliberate and can only be accomplished on the ground.

Fire protection is conventional but conservative, as shown in extra quantities of extinguishing agent and points of application in deference to the relative novelty of the installation.

Prior to the entry of General Motors as a customer for the first airplane, another nacelle configuration was designed by Convair (Fig. 7). This is still considered to be of sufficient merit to deserve further study but was replaced by the direct scoop-type inlet for first trials. This installation uses the entire nacelle as a plenum chamber, receiving its air from an annular scoop about the propeller spinner. It may be readily seen that installation should be substantially simpler, but several unknowns connected with fuel control and fire protection influenced Allison's preference for the direct scoop design. Both Allison and Convair plan to investigate thoroughly this type installation when more background knowledge is available from flight tests.

Performance of the 240 is materially improved with the 501, the primary gain being in increased take-off gross weight. As indicated by the curves, altitude has less effect on the turbine than on the reciprocating engine, which means higher pay loads from altitude airports and less loss of pay load because of en-route climb considerations. The first airplane will have a gross weight of 41,200 lbs., will cruise at 310 m.p.h. at 16,000 ft. at 75 per cent rated power, and will have a top speed at the same altitude of 350 m.p.h. Sea-level rate of climb is 1,940 ft. per min. Service ceiling is 32,500 ft.; take-off distance over a 50-ft. obstacle, non-C.A.R., is 2,150 ft., somewhat lower than for the standard 240 at the same weight. Altitude performance is so much better with the turbine that Convair is already revising their thinking to increase the pressurization differential from 3.5 lbs. per sq.in.

Comparing range pay-load curves of the turbine-powered airplane to that with reciprocating engines (Fig. 8) shows a substantial gain for short and medium ranges. The lower weight of the power plants adds to the pay load, a bonus that holds until the higher fuel consumption and range cause a reversal of balance. Choice of fuels has some influence on the range at which this balance occurs.

On the operational economics side, a comparison was drawn with currently projected models powered by reciprocating engines (Fig. 9). Certain assumptions

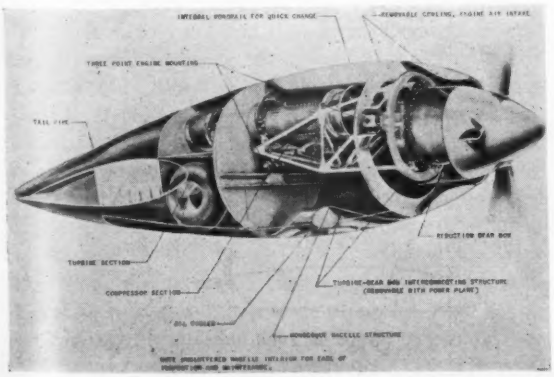

FIG. 7. Convair-Liner.

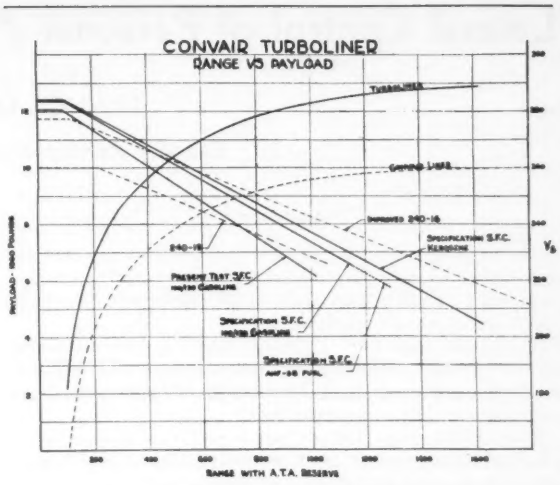

FIG. 8. Range pay load.

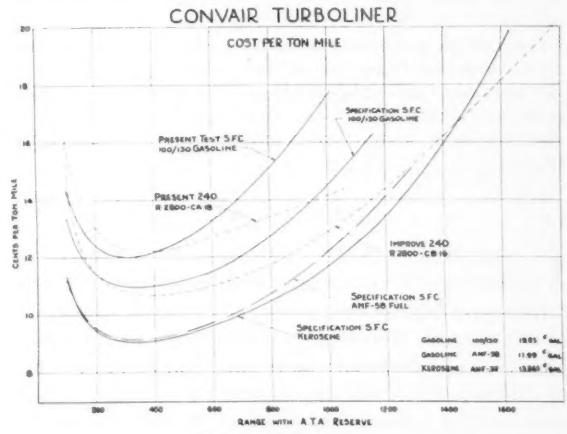

FIG. 9. Cost curves.

were made which are considered logical in the light of known trends. Outstanding are the following:

(1) No change in engine price. Previous discussion indicates this to be a conservative assumption.

(2) Maintenance costs the same. It might be added here that maintenance life between overhauls, as indicated by trends in jet turbines, can be expected to be as good, or better than, piston engines.

Time between overhauls seems to be an inverse function, and power output and specific fuel consumption appear to be direct functions of turbine wheel temperatures. Thus, one may be improved at any moment at the expense of the other considerations, with an overlying trend of improvement for all. This trend, measured in improvement of maintenance times on production jet turbines plotted against calendar and extrapolated into the future along a normal growth line, indicates that turbines can soon obtain 500-hour maintenance spans and should considerably exceed this figure by the time the 501 becomes commercially available. Some British propeller turbines have al-

(*Continued on page 35*)

Lateral Control of Personal Aircraft at High Lift Coefficients

FRANCIS M. ROGALLO*

Langley Aeronautical Laboratory, N.A.C.A.

ABSTRACT

The paper presents the results of N.A.C.A. research on three high-lift and lateral-control combinations that may be applicable to personal aircraft of high aerodynamic efficiency and discusses their lateral-control characteristics.

The combinations are: (1) plain and slot-lip ailerons on a wing with a full-span slotted flap; (2) plain aileron with full-span slotted flap retracting ahead of it; and (3) N.A.C.A. plug aileron on a wing with a full-span slotted flap.

From the data presented and from hypothetical applications to a representative light airplane, it appears that any of these lateral-control devices will provide control equal to that of conventional ailerons in the cruising condition and will provide much more powerful control in the landing condition. Improvements in both the performance and control of the aircraft are therefore possible.

Some of the problems encountered during the investigations are discussed, and others that will be encountered during application to personal aircraft are mentioned. Brief reference is made to drooped ailerons, which were found to be satisfactory only at small angles of droop because of their large adverse yawing moments.

INTRODUCTION

In 1947, the N.A.C.A. published a summary[1] of lateral-control research, including sections devoted to full-span flap configurations. In 1948, a collection[2] of test data for lateral control with full-span flaps was published and included a brief summary of these data. At the January, 1950, meetings of the Institute of the Aeronautical Sciences, 20 years of N.A.C.A. research on lateral-control devices suitable for use with full-span flaps was reviewed.[3] Each of these papers included results that should be applicable in the design of the lateral-control systems of personal aircraft capable of attaining high lift coefficients, but this information was sandwiched in between early data on flap and aileron configurations of high drag and recent data applicable primarily to large or high-speed airplanes. In the present paper, an attempt is made to extract the meat from this sandwich.

In 1939, the N.A.C.A. published a report[4] indicating that aerodynamic improvement can be obtained from the use of slotted flaps as compared with plain or split flaps, and many subsequent wind-tunnel and flight investigations of high-lift devices have provided confirmation. A program was undertaken concurrently to investigate lateral-control devices for use with full-span slotted flaps and resulted in several configurations that appeared to be aerodynamically satisfactory. These aileron arrangements, which are discussed in the present paper, fall into the three general types shown in Fig. 1. In the plain and slot-lip aileron combination, the plain aileron alone is used when the flap is retracted and the slot-lip aileron provides the control when the flap is fully deflected. Any part or all of the flap may be used as the plain aileron. In the plain aileron and retractable flap arrangement, the flap retracts into a well ahead of the aileron so that the same aileron may provide control with the flap either retracted or extended. Two of the many possible flap-extended positions are shown. The plug aileron is a combination spoiler and slot device that provides control at all flap deflections. It is a retractable aileron constructed in such a manner that when deflected it opens a slot for airflow through the wing.

PLAIN AND SLOT-LIP AILERONS

Wind-tunnel investigations of the plain and slot-lip aileron combination (see Fig. 1) on a rectangular wing[5,6] and on a complete model,[7–10] together with subsequent flight tests,[11] showed that this combination would provide adequate lateral control if the plain ailerons were used at small flap deflections and the slot-lip aileron at large flap deflections. Disadvantages of the combination are the number of ailerons required, together with their actuating mechanisms, and the difficulty of obtaining satisfactory control motions and forces from the slot-lip aileron in view of its limited down-travel and high upfloating tendency. In the N.A.C.A. application,[11] springs in the system were found necessary to prevent overbalance, as predicted from the wind-tunnel data.

Many variations of the plain and slot-lip aileron combination are possible. For example, in the develop-

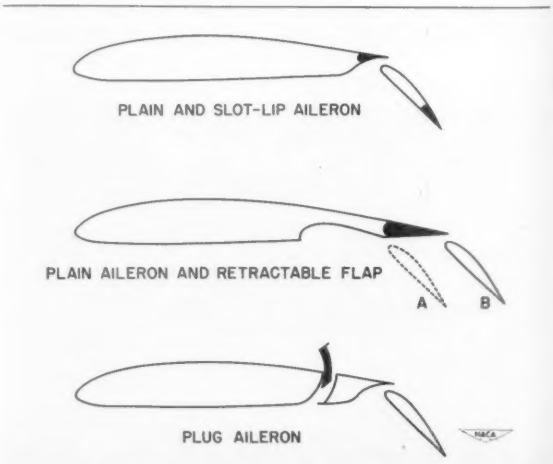

FIG. 1. Lateral-control devices on wings with full-span slotted flaps.

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* Stability Research Division.

ment of the system for the Kingfisher,[12] Chance Vought Aircraft Division, United Aircraft Corporation, started with a slot-lip aileron similar to that shown in Fig. 1 and a plain aileron that was essentially the outboard half of the span and the total chord of the slotted flap. This plain aileron configuration was retained, but, after a series of modifications, the slot-lip aileron evolved into a ventilated spoiler ahead of the slot lip, aerodynamically similar to the plug aileron of Fig. 1 to be discussed later. Having moved the spoiler forward of the slot lip, incidentally, Chance Vought found that it was not aerodynamically satisfactory until ventilated.

In addition to the development of the combination systems, both the N.A.C.A.[13] and Chance Vought[12] investigated the possibility of utilizing the trailing-edge aileron for control with the flap at various initial settings (drooped ailerons) and found that the reduction of aileron rolling-moment coefficient and the increase of aileron yawing-moment coefficient with flap deflection caused a progressive deterioration of control that became prohibitive with the flap deflected more than 20°. Although the rudder might be interconnected to offset the adverse aileron yawing moment in such a system, it seems likely that the available lateral control would decrease with reduction of airplane speed rather than increase as it does with some spoiler type controls, a more desirable variation.

Plain Aileron and Retractable Flap

The plain aileron and retractable flap combination of Fig. 1 is another arrangement that was developed by the N.A.C.A. in an effort to retain the trailing-edge aileron while using full-span slotted flaps. Two versions of the arrangement were investigted, as indicated by flap positions A and B. When the rearmost flap position is that with the flap nose near the aileron hinge line, position A, this flap is essentially a split flap. The portion of the span covered by the aileron has a high drag with the flap extended, but this drag may sometimes be tolerated if a low-drag flap, such as a Fowler[14] or an N.A.C.A. slotted flap,[15] is used inboard of the aileron. Because of the difference of flap configuration at aileron and inboard locations, this arrangement has generally been called full-span duplex flaps.

During the investigation of the duplex flap arrangement,[15] it became apparent that if the flap were moved back to the wing trailing edge, position B of Fig. 1, the aileron would be a slot-lip aileron, a device already found to have good lateral-control characteristics. The flap, moreover, would then be essentially a Fowler flap, an arrangement known to have good lift and drag characteristics. Such a combination might be used over the entire wing span, resulting in some simplification relative to the duplex flap arrangement. With these thoughts in mind, the N.A.C.A. investigated a full-span retractable flap in combination with a full-span aileron of small chord.[16,17] The arrangement was found to have good lift, drag, and control characteristics with the flap either retracted or fully extended, although

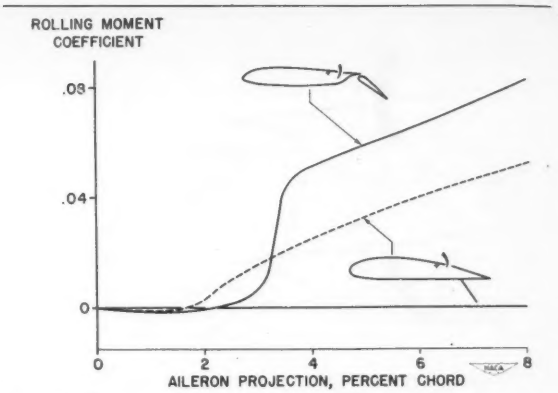

Fig. 2. Effectiveness of retractable ailerons on wings with full-span flaps.

a reduction of lateral control was experienced at intermediate flap positions. Obvious disadvantages of the arrangement are the required flap supporting system and the rather high wing pitching moments resulting from flap deflection as compared with the pitching moments of other flap arrangements.[17]

Plug Aileron

In an extensive investigation of spoiler-type lateral-control devices on wings with full-span split and slotted flaps,[18] it was found that unslotted spoilers are ineffective at small projections, especially with the high-lift flap deflected (see Fig. 2). Tuft studies on the wing with the split flap deflected showed that smooth flow was being re-established behind the spoiler at these small projections, probably because of the favorable pressure gradient produced by the split flap. In the slotted-flap arrangement, it is believed that projecting the spoiler induces a greater flow through the flap slot, thereby canceling the spoiling effect of the spoiler at small projections.

In the same investigation,[18] it was found that a slot through the wing below a flap-type spoiler, opened to allow airflow when the spoiler was deflected, greatly reduced the ineffective range. The difficulty of closing both the upper and lower ends of the slot to reduce the drag with the aileron neutral and of obtaining acceptable hinge moments discouraged further investigation of the flap-type spoiler and focused attention instead on a modification of the retractable aileron that has come to be known as the N.A.C.A. plug aileron (see Fig. 3).

It can be seen that the plug aileron conforms to the original wing contour on both the upper and lower surfaces when neutral. It is pivoted near the upper surface to allow as large upward projections as possible with a simple internal pivot, and at all upward projections it allows airflow through the wing to augment the spoiling action. A relatively large angular deflection of the plug is possible in the downward direction with little effect on the aerodynamic characteristics of the wing other than the hinge moments of the plug itself. This large allowable downward deflection of the plug aileron simplifies the attainment of good

FIG. 3. Geometry of the N.A.C.A. plug aileron.

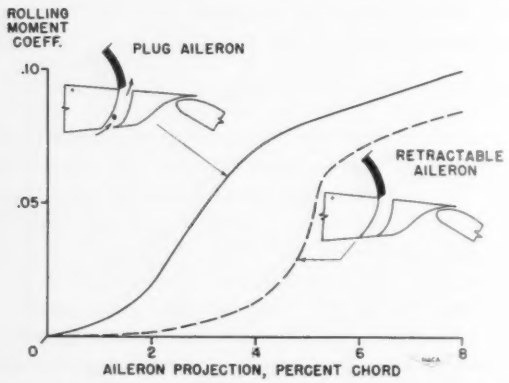

FIG. 4. Effectiveness of plug and retractable ailerons on a wing with a full-span slotted flap.

control force and displacement characteristics as compared with slot-lip ailerons, flap-type spoilers, and other arrangements in which motion from neutral is essentially limited to one direction.

A comparative investigation was made of plug ailerons and retractable ailerons (plug ailerons with the slot sealed at the bottom) on a rectangular wing with a full-span slotted flap.[19] The large effect of the slot, particularly at small spoiler projections with the slotted flap deflected, is illustrated by the typical set of curves shown in Fig. 4. The same configuration of plug aileron was also investigated in combination with a full-span split flap[19] and a full-span Fowler flap,[20] but in neither combination did it completely eliminate the ineffective region, showing again that the flap arrangement affects the plug-aileron characteristics. It is thought likely, however, that further development would improve the characteristics of these aileron and flap combinations.

Because the plug-aileron and full-span slotted-flap combination had appeared to be so promising from the wind-tunnel investigation,[19] the Navy decided to investigate this combination in flight on a Navy fighter, the modifications to be designed and constructed at the Naval Aircraft Factory.

Shortly before the airplane was to fly, the N.A.C.A. undertook a wind-tunnel investigation of a geometrically similar wing arrangement.[21, 22] The results indicated that the aileron characteristics would be satisfactory with the flaps down but that the rate of roll, flaps up, would probably be insufficient because of the short span and projection of the aileron and that the stick forces at high speed would be excessive on the fighter airplane. The favorable yawing moments were higher than on other devices investigated on the same wing.[17]

The pilot's opinion after several short flights seemed to be in general agreement with the wind-tunnel results, but, unfortunately, no quantitative measurements were made because at the close of the first day's testing the airplane was completely destroyed and the pilot killed in an accident attributed to malfunctioning of the slotted-flap actuating mechanism. After this accident, the Navy and the N.A.C.A. decided not to initiate further flight investigations of the plug aileron, largely because this device was by then undergoing development by Northrop Aircraft, Inc., for use on the P-61 Black Widow night fighter[23] and it was felt that additional flight investigations were unnecessary.

Ashkenas,[23] in describing the Northrop work, has told how the plug aileron was modified to reduce its hinge moments because the original configuration[19] would have resulted in excessive control forces on an airplane of the size and speed of the Black Widow. Preliminary flight tests of the plug aileron and slotted flap on the Black Widow showed that this configuration was generally satisfactory from the standpoint of lateral control and lift. Unfortunately, however, the thin, unsupported lower edge of the plug vibrated at high speed so as to damage the lower lip of the plug slot. After trying several modifications that reduced but did not completely eliminate this vibration of the plug aileron, the slot was sealed at the lower surface of the wing, thereby converting the plug aileron to a retractable aileron or spoiler. Thus modified, the aileron was found to be unsatisfactory at small projections with the slotted flap deflected. It was, however, considered satisfactory with the flap slot sealed, probably because

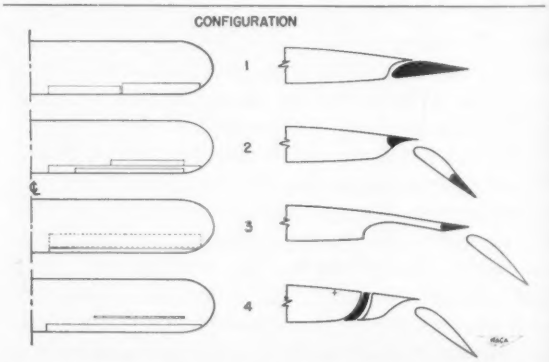

FIG. 5. Plan form and section drawings of the wing of a four-place light airplane equipped with several high-lift and lateral-control configurations.

TABLE 1

Geometric Characteristics of a Four-Place Light Airplane Equipped with Several High-Lift and Lateral-Control Configurations

Wing loading, 9 lbs. per sq.ft.
Wing span, 34 ft.; wing aspect ratio, 7.5.
Wing taper ratio, 1.0; flap chord/wing chord = 0.25.

Airplane Configuration	Flap Configuration	Aileron Configuration			
		Type	Aileron span / Wing span	Aileron chord / Wing chord	Projection or total deflection
1	Half-span slotted	Frise	0.44	0.20	42°
2	Full-span slotted	Plain (flap retracted)	0.60	0.10	40°
		Slot-lip (flap deflected)	0.40	0.10	40°
3	Full-span retractable	Plain	0.80	0.08	40°
4	Full-span slotted	Plug	0.50	...	0.10 wing chord

TABLE 2

Estimated Maximum Lift and Rolling Characteristics of a Four-Place Light Airplane Equipped with Several High-Lift and Lateral-Control Configurations

Airplane Configuration	Maximum Lift Coefficient, $C_{L_{max.}}$	Minimum Speed, $V_{stall(m.p.h.)}$	Rolling Effectiveness, $pb/2V$	Rolling Velocity at 1.1 V_{stall} (Deg. per Sec.)
(1) Flap 0°	1.52	48	0.11	29
Flap 40°	2.20	40	0.10	22
(2) Flap 0°	1.52	48	0.11	29
Flap 40°	2.68	36	0.15	29
(3) Flap 0°	1.52	48	0.11	29
Flap 40°	2.98	34	0.17	31
(4) Flap 0°	1.52	48	0.11	29
Flap 40°	2.68	36	0.21	41

deficiencies of the retractable aileron were masked by the feeler ailerons included in this particular application. An additional flight investigation[24] of the final arrangement on the Black Widow and of the retractable aileron alone (feeler ailerons locked in neutral) lends some support to this contention.

Although it is felt that a properly designed plug aileron would not require the addition of feeler ailerons, several other manufacturers of military aircraft have followed the Northrop lead in combining these small tip ailerons with plug or retractable ailerons. Discussion of these applications would add little of help to the personal airplane designer, even if national security permitted it.

ILLUSTRATIVE APPLICATIONS

The geometric characteristics of four different high-lift and lateral-control combinations, installed on otherwise the same personal airplane, are given in Fig. 5 and Table 1. The lateral-control systems are proportioned to give equal control with the flap retracted. Rough estimates of the maximum lift and rolling characteristics of these configurations are given in Table 2. The maximum lift characteristics are not adjusted for differences in tail load, which depend upon tail length, and the rolling-moment characteristics are not adjusted for the effect of differences in yawing moment. Nevertheless, the estimates given are considered sufficiently accurate to show what can be done with such devices. All of the configurations with full-span slotted flaps deflected show a considerable increase of maximum-lift coefficient and a substantial increase of aileron control relative to the partial-span flap configuration. Increments of maximum lift and rolling control at intermediate flap deflections are roughly proportional to the flap deflection. Increments of rolling control do not necessarily determine relative merit of the configurations, since these increments could be altered greatly by changes in size or deflection of the control devices.

The effects of the flaps on the take-off run, angle of climb, rate of climb, sinking speed, glide angle, and other performance characteristics of interest to personal aircraft designers are not presented or discussed in this paper, which is intended to cover only the lateral-control problem. The performance characteristics might well be the subject of another paper.

CONCLUDING REMARKS

In applying the data presented herein to the design of personal aircraft, the designer will no doubt be aware that some simplification and improvement of the aileron and flap systems may be possible because of the low speeds and the light air loads and control operating forces of personal aircraft relative to combat aircraft and that even further simplification may be necessary to keep the cost down. Slotted flaps, for example, will probably be mounted on simple hinge brackets with the pivot axis below the flap rather than on the multiple link systems or tracks often used on more expensive aircraft, and, when the plug aileron is used, it will probably not be combined with feeler ailerons.

A word of caution is also in order. Because this paper is devoted almost entirely to the discussion of lateral-control arrangements found to be aerodynamically satisfactory, with but a brief mention of some that were not, the impression may have been given that "you can't miss." Such is, unfortunately, not the case. The files of the N.A.C.A. and probably of some aircraft

companies are filled with data on devices that were found to be unsatisfactory. The devices that are discussed, however, are not represented as being in a fully developed state, to be turned over to the draftsman for production drawings without further engineering or testing. Compromises of shape, locations, motions, and clearances must be made, and often small changes will be found to affect critically the aerodynamic characteristics, especially the hinge moments. Methods of modifying and adjusting the hinge-moment characteristics of the devices discussed herein are given in the references, and, because of the relatively low speed and small size of personal aircraft, the attainment of acceptable control-force characteristics should be relatively easy.

Although the structural and mechanical problems will often determine the final choice of lateral-control and high lift devices, such problems are outside the scope of the present paper. It has been the purpose herein merely to discuss the aerodynamic characteristics of several devices that appear to be satisfactory from the aerodynamic standpoint and not to say which device will be best for the personal airplane in all respects. The answer to that question depends largely upon the ingenuity of the designer.

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I.A.S. Nineteenth Annual Meeting

Authors wishing to have papers considered for presentation at this meeting should submit outlines or short abstracts to the Meetings Committee, 2 East 64th St., New York 21, N.Y., no later than September 15, 1950.

Design Refinements in Modern Propellers

*By Thomas B. Rhines**

DESIGN REFINEMENT is a continuous process. In any article that has existed for many years in various forms, the process appears to be a slow one, with but few striking changes to attract one's attention. The degree to which the refinement process is active in aircraft propeller design can best be seen by observing, at one time, the accumulated effect of the refinements made over a period of years.

A single example will illustrate. In 1938, the DC-3 transport was equipped, for its 1,200-hp. engines, with propellers of 11.5 ft. diameter and weighing 397 lbs. each. In 1947, the DC-6 airplane appeared in service with 13-ft. propellers weighing 395 lbs. to absorb the 2,400 hp. of each engine. At substantially the same weight, the later propellers handle double the power, provide reverse braking operation, are equipped for synchronization, operate with a maximum pitch-change rate over three times as great, and, in addition, perform aerodynamically at a higher efficiency. Yet the propellers of both airplanes answer the same general description: aluminum-alloy blades, hydraulic operation, and standard Hydromatic hub structure. The differences represent design refinements.

From time to time, the emphasis in the refinement process appears to change from one aspect to another: from structure, to function, to aerodynamics. No matter where the greatest emphasis, all aspects must be continuously involved because they are always closely related. Today, however, the aerodynamic performance is the center of attention, as jet engines and propeller power plants are compared for various classes of aircraft. Aerodynamic design refinements are being examined carefully to help the propeller fulfill its mission for today's and tomorrow's airplanes.

Before discussing current activities in this field, it would be well to review a few fundamentals of propeller performance, remembering that refinements cannot change fundamentals; they can only advance performance closer to the ideal behavior. Propeller fundamentals, as for many applications of aerodynamics, lie in the basic mechanical concept of momentum. An "ideal" propeller of dragless airfoils would not provide an efficiency of 100 per cent unless it were infinitely large.

Figs. 1 and 2 show this fundamental aspect in the ideal performance of propellers for two specific flight speeds as a function of the power applied in relation to propeller diameter. The effect of rotational tip speed (expressed as propeller speed times diameter) leads to a wish for dragless airfoils and, particularly, for airfoils to be dragless at supersonic section speeds. Note that the ideal efficiency is only slightly influenced by the number of blades into which the propeller is divided. For easy

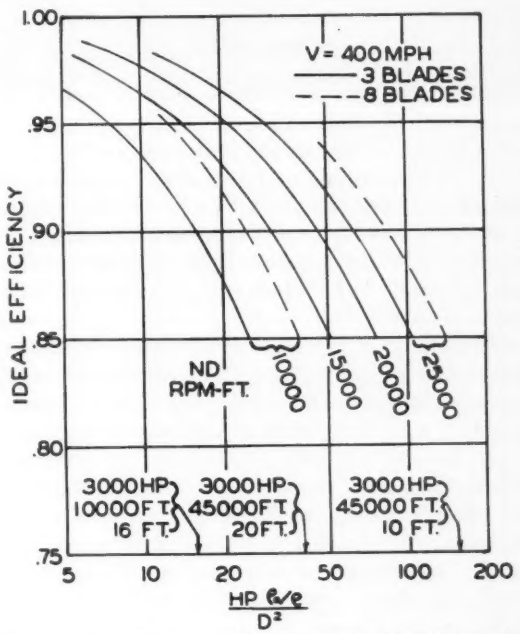

FIG. 1. Ideal efficiency with dragless airfoils at 400 m.p.h.

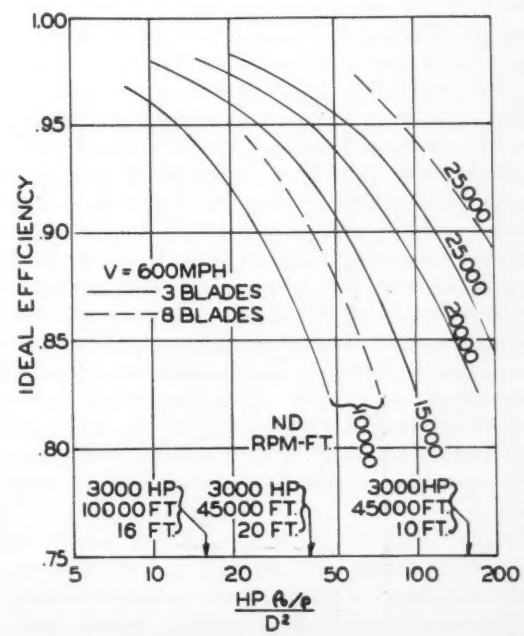

FIG. 2. Ideal efficiency with dragless airfoils at 600 m.p.h.

Presented at the Fifth Annual Flight Propulsion Meeting, I.A.S., Cleveland, March 24, 1950.

* Chief Development Engineer, Hamilton Standard Division, United Aircraft Corporation.

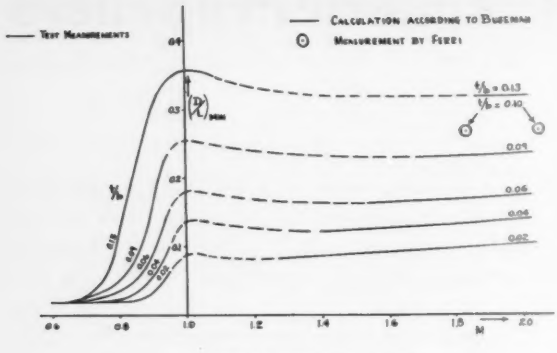

FIG. 3. Effect of airfoil thickness and operating Mach Number on airfoil performance.

interpretation of the abscissas of these curves, a few specific power, altitude, and diameter combinations are pointed out. The effect of high altitude (low density) on ideal performance should be observed. For further development of the subject of ideal propeller performance, reference 1, on which these curves are based, may be consulted.

In the light of the ideal performance indications, what should be done to achieve good levels of practical propeller efficiency? Obviously, the start is to make possible a good level of ideal performance by appropriate choice of propeller diameter for the power and altitude involved. This is basic. All aircraft propulsion schemes that operate by reaction on a mass of air are subject to the limitations imposed by momentum losses. The propeller provides the simplest means for moving a relatively large mass of air with consequently small momentum losses.

With the ideal propeller performance as a goal, the process of refinement works against the losses that reduce efficiency or that cause reductions in aircraft or engine performance. Propeller airfoil drag is one of the list; blade-to-spinner intersection drag is another.

Section drag, as it appears in propeller performance, provides a complex problem. The drag of each section of the blade depends upon section shape, local Mach Number, section loading, etc. The section shape is important to the propeller as a structure; the local Mach Number varies with flight condition (as do the structural loads), while the aerodynamic loading depends on the blade shape and on the flight operating condition. For many years it was satisfactory to simplify some of the related problems by approximations and use of rule-of-thumb procedures. More recently, the endless path of refinement has led to extensive use of propeller strip analysis for study of the problems, with related analyses of the propeller blade as a complex structure.

Propeller strip analysis will account for most of the variables in design and operation. Experience has shown that theory is reliable, within satisfactory limits, for relatively conventional propellers. Typical theory application neglects some factors, such as interaction between sections and boundary-layer action in centrifugal fields. It has, nevertheless, become an important tool for improvement of propeller blade design, by evaluating the complex effects of section loading, pitch distribution changes, airfoil camber modifications, and airfoil thickness.

The effects of section loading appear, in part, from the nature of propeller theory. The airfoil characteristics used in strip analysis are based on experiment and are applied to propeller use primarily as section drag data or as ratios of drag to lift. Fig. 3 shows a summary of drag characteristics as a function of section Mach Number and section thickness. This figure contains the key to one of the most fruitful sources of improvement in propeller performance at high airplane speeds, where section speeds reach or exceed the speed of sound; the airfoil sections must be as thin as structural requirements and weight considerations will allow.

Fig. 4 is the standard simple representation of two most important factors: the losses from high drag and the penalties of too high a value of V/ND. The theoretical benefits (for momentum reasons) in use of a high value of ND, as indicated in Figs. 1 and 2, supplement the teachings of Fig. 4; together they demand that propeller sections operate above the speed of sound over most of the blade length whenever airplane speeds are above a Mach Number of about 0.85. Propeller performance then depends primarily on supersonic section drag.

Such are the indications from propeller theory. The theory is, however, imperfect. Its demonstrated adequacy for routine refinement steps does not prove that it will properly handle the problems met in further advancing propeller performance. Practical test results are required and are daily becoming available.

At United Aircraft, a wind tunnel of 8-ft. throat operates to a tunnel Mach Number of about 0.92 for tests on a propeller dynamometer of 4-ft. models. In this facility, the aerodynamic detail of blade design is examined by conventional test procedures. Fig. 5

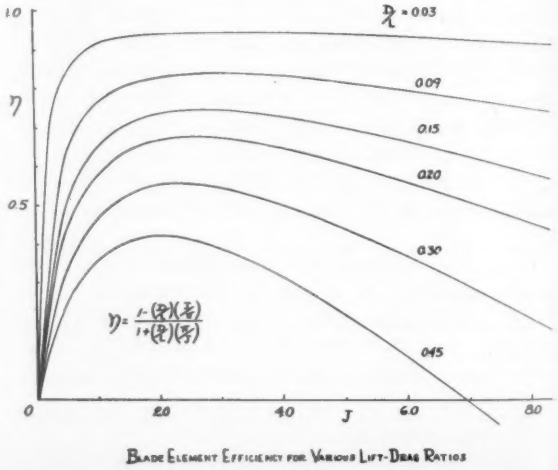

FIG. 4. Blade element efficiency for various lift-drag ratios.

shows the general test setup. Fig. 6 represents a typical set of test results in standard coefficient form. This particular sample is from runs made at a Mach Number of 0.713.

In Fig. 7 is an envelope curve summary of test results for several two-blade propellers, shown in comparison with a typical World War II blade design. It is apparent that design refinements have removed a fair proportion of the losses that were once experienced in operation at moderate Mach Numbers and that the flight speed at which large losses begin to appear has been moved upward in Mach Number about 0.1.

For operation at the peak efficiencies of Fig. 7, certain propeller application conditions must be observed. The lower curves of this figure define those conditions for one of the propellers as found by test. These curves disclose three distinct operating régimes. The first, at low flight speeds, is not concerned with supersonic flow, and peak performance is achieved by operation at a particular V/ND. In that condition, the power absorbed is extremely low for low flight speeds, and, in practice, no attempt is made to operate at the peak of the envelope curves. Lower efficiencies are accepted to allow relatively smaller propellers.

The second régime appears at a forward Mach Number of about 0.5, where tip section speeds approach critical values. This régime is one of increasing V/ND as speed rises and ND drops slightly in an effort to avoid losses due to high section drag. At nearly Mach Number 0.8, the losses from excessive V/ND begin to exceed those directly chargeable to section speed, and the third régime begins. At the highest speeds, much of the blade is supersonic at a desirable

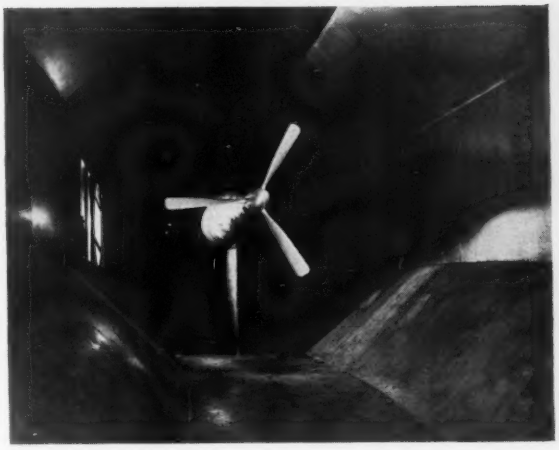

FIG. 5. Model propeller on dynamometer in United Aircraft wind tunnel.

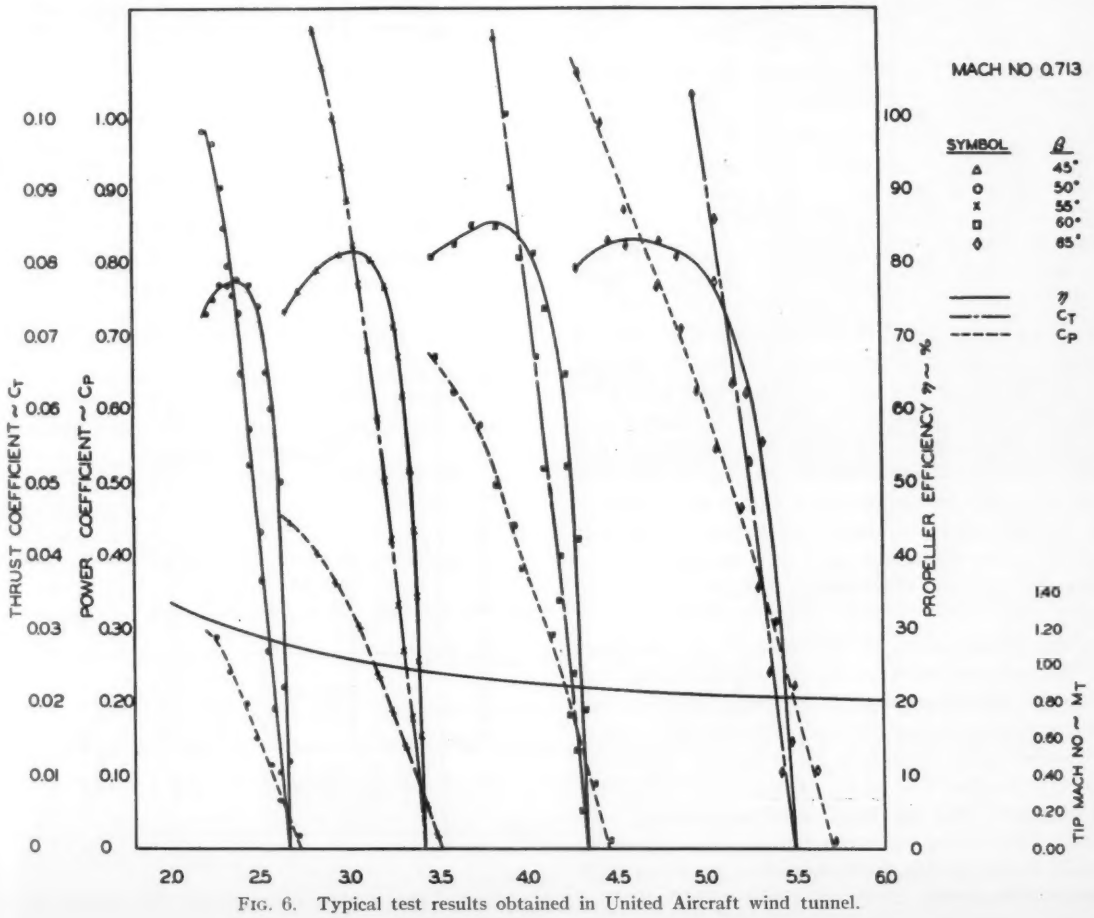

FIG. 6. Typical test results obtained in United Aircraft wind tunnel.

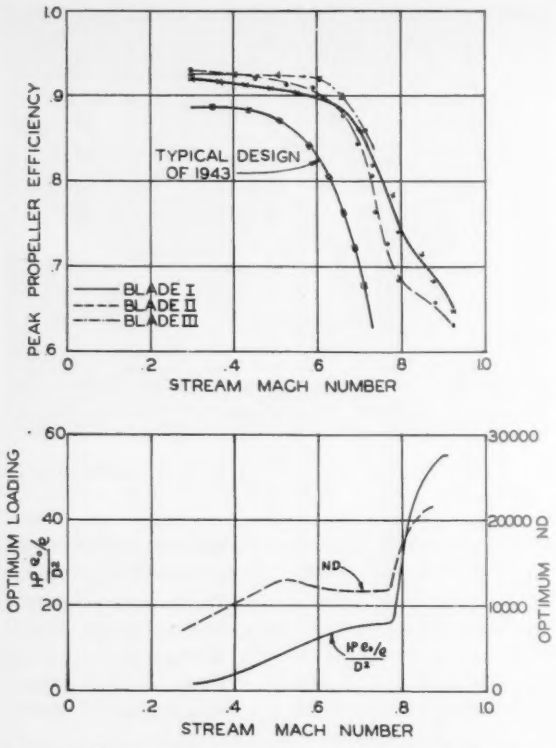

FIG. 7. Summary performance and operating conditions for several model propellers.

value of V/ND but with severe losses from section drag.

The condition at high speed is such as to allow a marked decrease in propeller size as compared with conditions in the moderate speed régime. For peak performances, the diameter can be about two-thirds as large, but a practical figure is more nearly three-fourths, since most cases will have resorted to some overloading at the lower speed.

A comparison of the tests of these three blades can show an example of a single step in the areodynamic design refinement process. All three have the same plan form; they differ in camber and thickness over the blade radius as shown in Fig. 8. Blades I and II differ in thickness but have the same camber; blades I and III differ in camber with the same thickness. The varying effects of these differences in different flight-speed ranges appear in Fig. 9, showing the envelope efficiencies at three values of flight Mach Number.

At the lowest speed, the blade of greater thickness and tip camber is best; at the two higher speeds, it is worst. The thin blade of high tip camber is poor at low speeds and intermediate at Mach Number 0.713, where low camber gives improved performance. These results serve to illustrate an important point in the current situation—that the detail aerodynamic design of a propeller blade, for optimum performance, must be carefully related to the flight conditions for which high efficiency is required.

In this test example, the value of thin airfoils for high speed is clear; this result is characteristic and is not peculiar to the particular set of blades chosen for illustration. The results lead directly to predictions of the characteristics of "supersonic" propellers, the next step in the process of design refinement. However, first, it should be noted that the "supersonic" propeller need not be a fundamentally different article from a conventional unit. The conventional unit, operated at high airplane speed and at a moderate V/ND achieved by high tip speed, is a "supersonic" propeller; but, as Fig. 7 shows, it needs refinement to reduce section drags.

A prediction of the extent to which performance can be improved by drag reduction for supersonic operation depends largely on the degree to which airfoil thickness can be reduced. Refinement in this direction has already been profitable for conventional operation and is one of the several factors involved in the blades of Fig. 6 in comparison with the typical 1943 design. Further changes are largely dependent on structural refinement to allow thinner blades, wider blades to reduce thickness ratios without impossible physical thickness, mechanical refinement to handle the

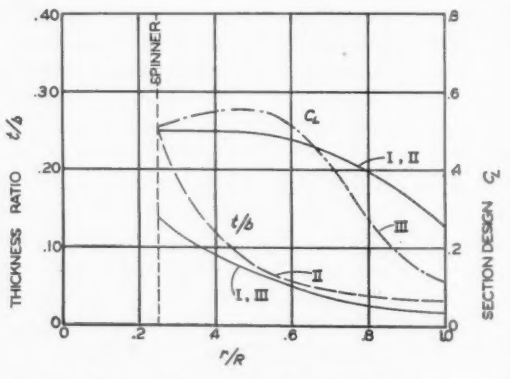

FIG. 8. Principal shape characteristics of model blades.

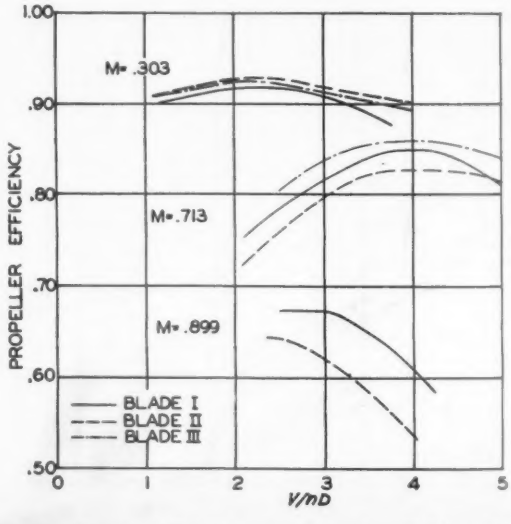

FIG. 9. Envelope efficiency curves for various flight speeds.

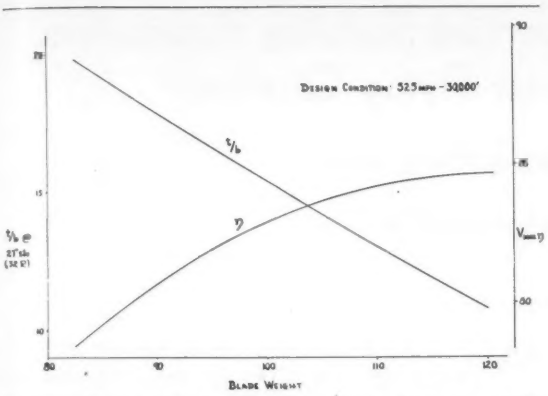

FIG. 10. Blade weight as a function of blade thickness and high speed efficiency.

high twisting moments of wide blades at high rotational speeds, improved spinner-blade junctures for larger blade chords, and plan-form improvements to avoid flutter and vibration problems from aerodynamic excitation. Altogether, it is probable that efficiencies better than 75 per cent, and perhaps approaching 80, can be achieved at Mach Number 0.9—provided that near-optimum operating conditions and diameters are used.

The practical limits for low blade thickness at high section velocities cannot yet be stated with certainty. The limits depend in part on an old problem that has no unique solution: What is a fair price for efficiency improvement when the medium of exchange is pounds avoirdupois? Fig. 10 illustrates the problem for a hypothetical blade as it is shown by a design study.

This result is probably typical for a blade to be used at high section speeds, where structural problems are great. Centrifugal loads and steady moments are, of course, still in the problem. In addition, the requirements for control of flutter must be included. And, in particular, the influence of aerodynamically excited vibrations may become critical.

At moderate airplane speeds, the blade bending stresses associated with propeller rotation in the unsymmetrical air stream are only slightly greater than for a purely forced vibration; a "magnification factor" of 1.4 or 1.5 is normal. For high blade-section speeds with thin blades, the magnification may rise to large values as operation approaches resonance. Design must strive for inherently stiff blades to reduce the proximity to resonance without too much use of thickness as an easy source of stiffness. Detail refinement will play a large part in this work as various plan forms and thickness distributions are studied to learn their effects on the combined aerodynamic and structural problem.

As a conclusion to this brief review, a few "refinements" that will probably never appear in practice might be displayed. They are evidence that the refinement process is, in large part, exploratory in nature. Fig. 11 shows several wind-tunnel-model blades, including conventional types along with the more radical attempts.

REFERENCE

[1] Crigler, John L., and Talkin, Herbert W., *Charts for Determining Propeller Efficiency*, N.A.C.A. A.C.R. No. 14129, September, 1944.

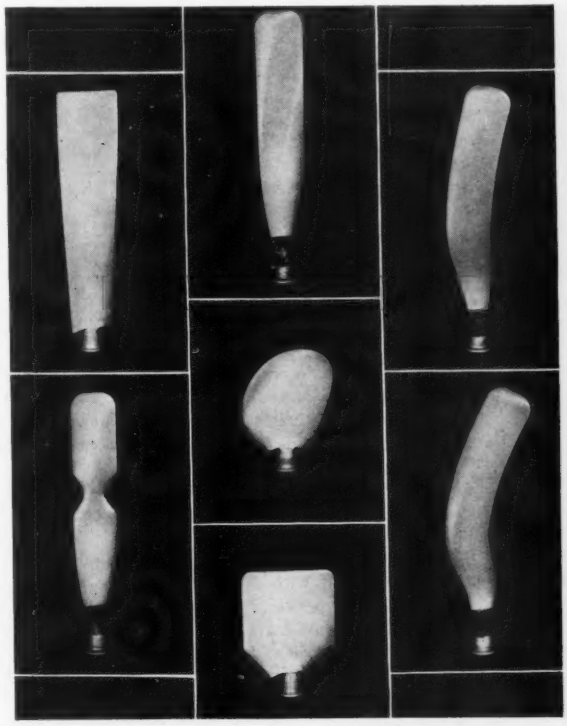

FIG. 11. Wind-tunnel model blades for design studies.

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An Explanation of Some Important Stability Parameters That Influence Helicopter Flying Qualities

ALFRED GESSOW* and KENNETH B. AMER*

Langley Aeronautical Laboratory, N.A.C.A.

SUMMARY

An attempt is made in this paper to provide some understanding of the stability and control parameters that influence the flying qualities of the helicopter to engineers interested in rotating wing aircraft but with no specialized training in stability theory. An explanation is made of these parameters in terms of fundamental physical quantities. The means for rotor control and the source of rotor damping, the two quantities that together determine an important handling characteristic—control sensitivity—are discussed. Static stability with speed and with angle of attack are also explained, and it is shown that both aspects must be considered for a correct evaluation of the flying qualities of the helicopter.

SYMBOLS

T = rotor thrust, lbs.
L = airplane lift, lbs.
V = true air speed of helicopter or airplane along flight path, ft. per sec.
S = airplane wing area, sq.ft.
ρ = mass density of air, slugs per cu.ft.
Ω = rotational velocity of rotor, rad. per sec.
C_L = airplane lift coefficient, $L/{}^1/_2 \rho V^2 S$
ω = angular velocity of helicopter (pitching or rolling), rad. per sec.
γ = mass constant of rotor blades; expresses ratio of air forces to mass forces (γ is inversely proportional to blade moment of inertia about flapping hinge)
δ = angular displacement of rotor cone due to angular velocity of helicopter, rad.
ϵ = angular displacement of rotor cone due to a control displacement or fuselage angle-of-attack change, rad.
M = pitching moment, ft.lbs.
M_ω = damping in pitch or roll (rate of change of pitching or rolling moment with pitching or rolling velocity), ft.lbs. per rad. per sec.
M_V = stability with speed (rate of change of moment with translational velocity), ft.lbs. per ft. per sec.
M_α = static stability with angle of attack (rate of change of moment with angle of attack), ft.lbs. per rad.
T_α = rate of change of thrust with angle of attack, lbs. per rad.
α = fuselage angle of attack, deg.
l = distance between rotor thrust vector and helicopter center of gravity in trimmed flight, ft.
h = height of rotor hub above helicopter center of gravity, ft.
e = offset of flapping hinges from the rotor center of rotation, ft.
U_T = component at blade element of resultant velocity perpendicular to blade-span axis and to rotor shaft, ft. per sec.
U_P = component at blade element of resultant velocity perpendicular both to blade-span axis and U_T, ft. per sec.
α_r = blade-element angle of attack measured from line of zero lift, rad.

Presented at the Rotating Wing Aircraft Session, Eighteenth Annual Meeting, I.A.S., New York, January 23–26, 1950.

* Aeronautical Research Scientists.

INTRODUCTION

WITHIN RECENT YEARS, the importance of satisfactory flying qualities for the fixed-wing airplane has become an accepted fact. As a result of this recognition, military and civilian aircraft specifications incorporate minimum flying-qualities requirements. It is only recently that serious efforts have been made in the direction of establishing similar requirements in helicopter specifications. The importance of satisfactory helicopter flying qualities was pointed out in a recent paper[1] which stated that future Navy helicopter specifications would incorporate stringent flying-qualities requirements.

N.A.C.A. flight-test experience with various makes and types of helicopters[2,3] has indicated that there are certain primary stability and control requirements that must be satisfied before the helicopter can be said to have satisfactory handling qualities. These requirements may, in some cases, depend solely on the mechanical design of the helicopter, control-friction limits being an example. In most other cases, the requirements are primarily aerodynamic in nature and depend on the response of the rotor and fuselage to control motions or atmospheric disturbances. An example of an aerodynamic requirement is the one proposed in a recent *N.A.C.A. Technical Note*,[3] which deals with the response of the helicopter during a pull-up maneuver in forward flight. It is the object of the present paper to explain the sources of the most important of those aerodynamic stability and control characteristics that are known to affect helicopter flying qualities. The explanation, directed primarily toward those engineers interested in rotating wing aircraft but with no specialized training in stability theory, will be made in terms of fundamental physical quantities.

The subject will be introduced by a discussion of the means of helicopter control and of rotor damping due to a pitching or rolling velocity, these two factors determining an important handling characteristic—control sensitivity. Two additional important stability characteristics that will be discussed are static stability with speed and static stability with angle of attack, the latter being objectionably deficient in many present-day helicopters. The need for considering both these aspects of static stability will be brought out.

In this paper, only the single-rotor helicopter with fully articulated blades and a conventional control system is considered, since it is the fundamental configuration.

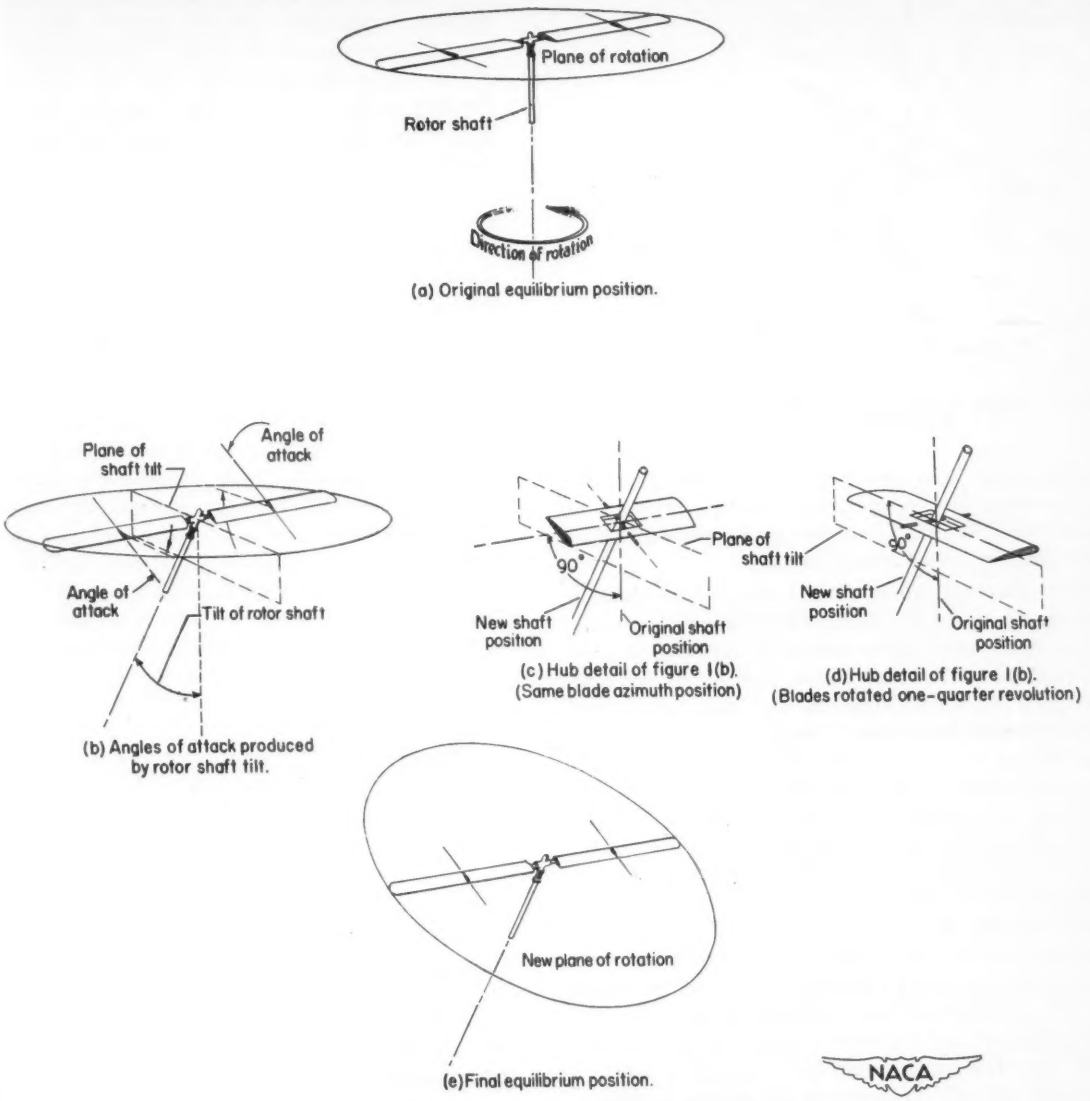

FIG. 1. Effect of rotor-shaft tilt on the tip-path plane.

DEFINITIONS

The following stability definitions are given for terms used herein:

Trim.—An aircraft is trimmed in steady flight when the resultant force and moment on the aircraft are equal to zero.

Aircraft Stability.—Stability is related to the behavior of an aircraft after it is disturbed slightly from the trimmed condition.

Static Stability.—An aircraft is statically stable if there is an initial tendency for it to return to its trim condition after an angular displacement or after a change in translational velocity from that condition; it is unstable if it tends to diverge from trim after being displaced. An aircraft is neutrally stable if it tends to remain in the condition to which it has been displaced.

Dynamic Stability.—The dynamic stability of an aircraft deals with the oscillation of the aircraft about its trim position following a disturbance from trim.

Helicopter nose-up moments, angular displacements, and angular velocities are assumed to be positive. Changes in translational velocities in the direction of increasing velocity, as well as upward forces, are also positive.

In this paper, rotor thrust is assumed to act perpendicular to the tip-path plane. This assumption is sufficient for a qualitative understanding of helicopter stability and control, although it may lead to serious quantitative errors in certain flight conditions.

ROTOR CONTROL

The means for controlling the conventional helicopter can be visualized by considering a system, such as that

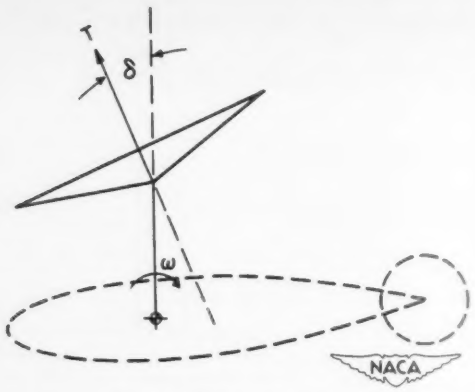

FIG. 2. Source of rotor aerodynamic and mass moments about helicopter center of gravity.

shown in Fig. 1, composed of a shaft rotating counterclockwise (as viewed from above) and to which are attached two blades that are free to flap about a chordwise axis perpendicular to the shaft.

If the shaft is suddenly tilted to the position shown in Fig. 1b, the blades will realign themselves perpendicular to the shaft only if forces normal to the tip-path plane are produced as a result of the shaft tilt to force the blades to follow. Inasmuch as the blades are hinged, no mechanical forces can be transmitted. If the rotor were located in a vacuum, no aerodynamic forces would be produced, and, hence, the tip-path plane would remain in its original position. Examination of the schematic detailed views of the rotor hub in Figs. 1c and 1d shows that this condition of no tip-path-plane tilt is mechanically possible. Under actual operating conditions, however, the tip-path plane will follow after a short interval of time because of the air forces that are produced as a result of the shaft tilt. As can be seen in Fig. 1b, the tilt of the shaft causes the angle of attack of the blades to change cyclically. Thus, the blade moving to the left has an increased lift and moves up to a maximum positive displacement one-quarter revolution after the position of maximum lift. The blade moving to the right has a decreased lift and moves down to a maximum negative displacement one-quarter revolution after the position of maximum negative lift. Therefore, a short time later, the plane of rotation is again perpendicular to the rotor shaft as shown in Fig. 1e.

Thus, although by tilting the shaft it was impossible to force physically the hinged blades to align themselves with the shaft, the tilt produced a cyclic change in blade angle of attack such that the air forces brought the blades into proper alignment.

This idea can be applied directly to a helicopter in that, if the rotor shaft is tilted, the rotor will quickly realign itself with respect to the shaft. A movement of the control stick of a conventional helicopter is equivalent to tilting the shaft with respect to the fuselage. The resulting tilt of the rotor with respect to the fuselage will produce a moment about the helicopter center of gravity because the rotor thrust, which acts approximately perpendicular to the tip-path plane, is displaced from the center of gravity. An additional source of moment is provided by the rotor tilt if the hub has flapping hinges that are offset from the rotor shaft. This moment is caused by the centrifugal force in the blades.

The two sources of moment are illustrated in Fig. 2, which shows that the moment about the helicopter center of gravity produced by a unit stick displacement (which may be defined as the control power) is increased by an increase in the vertical distance between the rotor hub and the helicopter center of gravity or by an increase in the flapping-hinge offset. Although the vertical height of the center of gravity is not usually a design variable, control power may be adjusted to a considerable extent in the design stage through the use of offset flapping hinges. An increase in control power through the use of offset flapping hinges is desirable in order to maintain adequate control during maneuvers in which rotor thrust is reduced, inasmuch as this source of moment is independent of rotor thrust. Offset flapping hinges also permit an increase in the allowable center-of-gravity range of the single-rotor helicopter. (The moment due to a shift in center of gravity must be compensated for by a control moment in order to maintain the helicopter in trim. Inasmuch as the amount of control displacement is limited for mechanical reasons, an increase in the amount of control power is the feasible way to allow for a greater center-of-gravity travel.)

DAMPING IN PITCH (OR ROLL)

The foregoing discussion points out that, because of blade inertia, some delay exists between a rapid shaft tilt and the realignment of the rotor with the shaft. Thus, if the shaft continues to tilt, the tip-path plane will continue to lag behind the rotor shaft and, in so doing, supplies the aerodynamic moment necessary to overcome continuously the flapping inertia of the rotor during steady pitching or rolling.

If the aerodynamic and inertia flapping moments are equated, the following result for the angular displacement of the rotor plane with respect to the shaft per unit tilting velocity of the shaft is obtained for the hovering case:*

$$\delta/\omega = 16/\gamma\Omega \qquad (1)$$

The dimensions of the quantities of either side of Eq. (1) will be noted to be the units of time. The quantity $16/\gamma\Omega$ can be interpreted physically as follows: If the rotor shaft is tilting at any constant angular velocity, the thrust vector reaches a given attitude in space $16/\gamma\Omega$ sec. after the rotor shaft has reached that attitude.

* A derivation of Eq. (1) may be found in reference 4. The effect of tip-speed ratio, which is of second order, may be easily derived.

If a helicopter is tilted at an angular velocity ω, as shown in Fig. 3, the ensuing lag of the rotor plane displaces the thrust vector and thus produces a moment about the center of gravity. If offset hinges are present, there is an additional moment due to the tilt, as explained in the section titled "Rotor Control." Moments due to tilting velocity are known as "damping in pitch" or "damping in roll," depending upon the axis about which the tilting occurs, and can be expressed mathematically as $\Delta M/\Delta\omega$ or M_ω. Because this moment is opposite to the tilting velocity for the conventional rotor with the assumption that the thrust is perpendicular to the tip-path plane, M_ω is stabilizing and, according to the convention, is negative in sign.

As indicated in Eq. (1), the amount of rotor tilt for a given angular velocity is inversely proportional to the rotor r.p.m. and to the blade mass factor γ (and, hence, directly proportional to blade moment of inertia). It follows, therefore, that small helicopters, which operate at high r.p.m. in order to maintain reasonable tip speeds, will tend to have less rotor damping than large helicopters

The value of blade mass factor γ is reduced to a considerable extent for helicopters powered by blade tip-jet units. Tip-jet-powered helicopters would therefore be expected to have considerably more rotor damping than conventionally powered helicopters. In addition, γ may vary appreciably because of differences in blade construction, although this effect is less marked than the effect of adding tip units.

In addition to the effects of rotor r.p.m. and γ, rotor damping may be increased by the use of devices that act upon the control system in such a manner as to increase the displacement of the rotor from its trim position due to a given rate of roll or pitch. An example of such a device is a rate gyro that would apply opposite control by an amount proportional to the rolling or pitching velocity of the helicopter. Increased effective damping is achieved by the Bell Stabilizing Bar and the Hiller Control Rotor, both of which act on the same principle as the rate gyro.

Thus far, design factors and devices that affect rotor damping by affecting the amount of rotor tilt for a given pitching or rolling velocity have been discussed. Rotor damping may also be varied by changing the moment due to a given rotor displacement. The damping moment produced by a given rotor displacement will depend upon the rotor height and the amount of offset of the flapping hinges.

Control Sensitivity

The combination of control power and damping in roll (or pitch) together determine an important flying-qualities characteristic. This characteristic is called "control sensitivity" and may be defined as the maximum rate of roll (or pitch) achieved by a unit displacement of the controls. Control sensitivity may be defined in three alternate ways as follows:

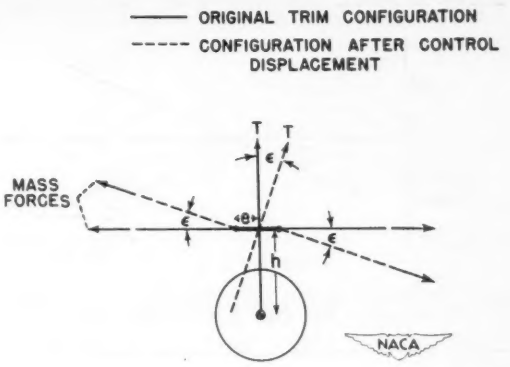

FIG. 3. Source of damping in pitch for a helicopter as a result of pitching velocity.

$$\text{Control Sensitivity} \begin{cases} = \dfrac{\text{control power}}{\text{rotor damping}} \\ = \dfrac{\dfrac{\text{control moment}}{\text{stick displacement}}}{\dfrac{\text{damping moment}}{\text{angular velocity}}} \\ = \dfrac{\text{angular velocity}}{\text{stick displacement}} \end{cases}$$

Physically, the manner in which control power and damping determine control sensitivity may be understood from the following argument: If the control stick is displaced (laterally, for example) and held, the helicopter will initially accelerate angularly at a constant rate that is inversely proportional to the moment of inertia of the helicopter about its longitudinal axis. [This result follows from Newton's Law, $M = I\,(d\omega \div dt)$.] As the angular velocity builds up, the opposing damping-in-roll moment increases in proportion until an angular velocity is reached at which the damping moment is equal to the control moment. The helicopter is therefore stabilized at that angular velocity, because the resultant moment on the helicopter is zero. It is thus apparent that, if the rotor damping is large with respect to the control power, the maximum rate of roll reached by the helicopter by a given stick displacement would be small, inasmuch as a sufficiently large damping moment would be produced at a small rolling velocity to balance the control moment. Alternately, it is clear that, if rotor damping is small with respect to the control power, the maximum angular velocity attained by a given stick displacement would be large.

Helicopters with conventional control systems are subject to high control sensitivity. In fact, according to reference 2, the maximum rate of roll achieved by a small two-place helicopter may be as great as those of some modern fighter airplanes at the speeds for their maximum rates of roll. This is true not because of high control power but rather because of low damping, which, for the helicopter, is a fraction of that for airplanes. This same reference goes on to state that high

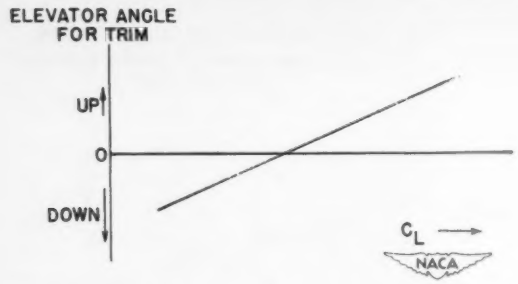

FIG. 4. Static-stability curve of a typical airplane obtained in gliding flight. This curve is independent of speed.

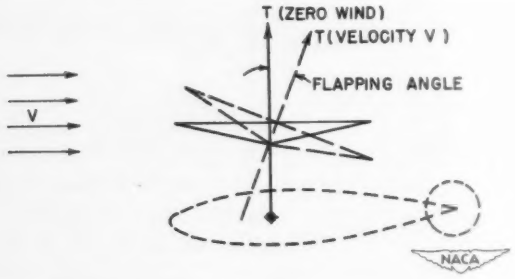

FIG. 5. Effect of translational velocity on attitude of rotor tip-path plane.

control sensitivity can lead to overcontrolling, which in turn results in a short-period pilot-induced lateral oscillation.

It is worth while to point out which of the physical characteristics of the helicopter have a marked influence on control sensitivity. The height of the rotor and the offset of the flapping hinges do not affect control sensitivity because they change control power and rotor damping in proportion. Design factors and devices that increase rotor damping without affecting control power result in reduced control sensitivity. Thus, large helicopters operating at low r.p.m.'s, helicopters with tip-jet units, and helicopters with devices such as the Bell Stabilizer Bar and the Hiller Control Rotor will have reduced control sensitivity.

Although rotor height and flapping-hinge offset do not affect control sensitivity, the ratio of these values to the fuselage moment of inertia will determine, to a large extent, the time necessary to reach the maximum angular velocity.

STATIC STABILITY WITH SPEED AND WITH ANGLE OF ATTACK

Inasmuch as an aircraft can be displaced in pitch (angle-of-attack change) or by a change in forward speed, two aspects of static stability exist because of the two sets of forces and moments produced by these two changes. Before proceeding with a discussion of the helicopter, it is considered worth while to make a comparison with the static stability of the airplane to show the similarities and the differences between the two.

Comparison with the Airplane

If an airplane is flying in a trimmed position and the angle of attack is increased while its speed is kept constant, the airplane is statically stable with respect to angle of attack if the resulting aerodynamic moment is a nose-down moment.

Consider now the static stability of an airplane with changes in speed and with angle of attack kept constant. If power and Mach Number effects are neglected, an assumption that is justified for the present discussion, a variation in speed from trim speed while the angle of attack and flight path are kept constant (as could be done in a wind tunnel) produces no aerodynamic moment about the center of gravity. In other words, the airplane is neutrally statically stable with speed at constant angle of attack because no change is obtained in lift or moment coefficients with speed. A given speed change from trim while maintaining constant angle of attack merely changes all of the aerodynamic forces and moments acting on the airplane in the same proportion, and the airplane is thereby maintained in trim. (For the airplane in flight, such a speed change at constant angle of attack would cause a change in lift and, hence, in flight-path angle sufficient to return the airplane to the trim speed.)

Because the airplane has neutral stability with speed at constant angle of attack, it is only necessary to determine the static stability with angle of attack. This is done in flight by obtaining the variation of stick position with speed, the speed being readily converted to lift coefficient or angle of attack. The fact that the air speed is changing while the angle of attack is changing does not affect the result, inasmuch as a change in speed at constant angle of attack does not change the trim of the airplane. A typical representation of the static stability of the airplane is shown in Fig. 4.

When the effect of propeller operation or Mach Number is considered, however, a single curve, such as that given in Fig. 4, is no longer sufficient, since the airplane is no longer neutrally stable with speed at constant angle of attack. Because, as will now be shown, the helicopter has positive and not neutral static stability with speed, it follows that, like the airplane in the high-speed or power-on condition, a single curve does not suffice.

Rotor Stability with Speed

Consider a rotor mounted on a helicopter which is subjected to a translational velocity. The effect of this translational velocity is to tilt the tip-path plane in a direction away from the velocity of translation, as shown in Fig. 5. This tilting of the rotor plane is a result of blade flapping that arises from differences in lift on the advancing and retreating blades brought about by differences in velocity. Blade flapping, which cyclically varies the blade angle of attack, tends to equalize these differences in lift. The rotor plane will tilt farther backwards (that is, flapping will increase) with increasing translational speeds, inasmuch as the velocity of the

advancing blades becomes increasingly greater than the velocity of the retreating blades. Fig. 5 indicates that this tilt of the rotor plane due to translational velocity will produce a moment about the helicopter center of gravity. The moment will be nose-up with increasing speed and nose-down with decreasing speed. The variation of moments due to changes in translational velocity is a measure of stability with speed, which can be expressed mathematically as $\Delta M/\Delta V$ or M_v. Inasmuch as nose-up moments are considered positive, M_v is always positive for the conventional helicopter rotor.

Rotor Stability with Angle of Attack

As shown in Fig. 1, a change in attitude of the hovering helicopter (which is prevented from translating) results in an equal tilt of the rotor plane, with the result that no rotor moment or change in thrust occurs. Thus, the hovering helicopter has neutral stability with attitude change. In forward flight, however, a change in longitudinal attitude (fuselage angle of attack) will produce a rotor moment and a thrust change. This moment due to a change in fuselage angle of attack at constant velocity arises from the change in flapping (tilt of the rotor plane relative to the fuselage) and can be understood by an examination of Fig. 6. Consider a nose-up change in fuselage angle of attack α from the trim value as shown in Fig. 6a. The changes in relative velocities and angle of attack of a typical blade element which result from this change in fuselage angle are shown in Fig. 6b, where U_P, U_T, and α_r represent trimmed values. The change in blade-section angle of attack $\Delta\alpha_r$ is equal to $\Delta U_P/U_T$ (for the usual assumption of small angles included in helicopter analyses), and the change in lift at this section, which is proportional to $\Delta\alpha_r U_T^2$, is therefore proportional to $\Delta U_P U_T$. Inasmuch as ΔU_P is constant over the rotor disc (the component of flight velocity through the disc is constant over the disc), the change in lift due to the change in fuselage angle of attack is greater on the advancing blade where U_T is highest. This unequal increase in lift between the advancing and retreating blades is compensated for by increased flapping or a backward tilt of the rotor cone with respect to the fuselage. At the same time, the increased lift at all sections results in an increase in the magnitude of the rotor thrust. Fig. 6 shows that this tilt of the thrust vector with respect to the fuselage, which results from the nose-up change in fuselage angle, produces a nose-up moment about the fuselage center of gravity which is accentuated by the increased magnitude of the rotor thrust. If a nose-down change in fuselage angle had been considered, the result would have been a forward tilt of the rotor cone relative to the fuselage and a reduction in thrust. Inasmuch as a change in angle results in a change in magnitude, as well as a tilt, of the thrust vector, doubling a nose-up change in angle more than doubles the nose-up moment. Conversely, doubling a nose-down change in angle results in less than doubled nose-down moment but, nevertheless, a nose-down moment.

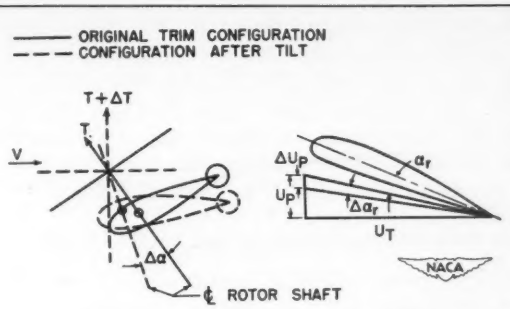

FIG. 6. Effect of change in fuselage angle of attack on resultant rotor force. (a, *left*) Side view of helicopter. (b, *right*) Velocity diagram of typical blade element.

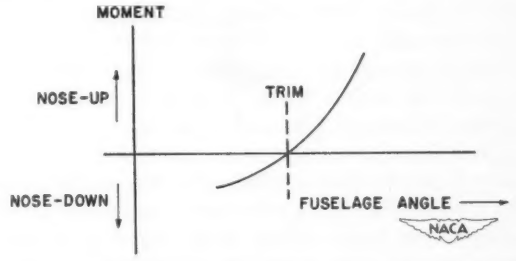

FIG. 7. Pitching moment contributed by rotor about helicopter center of gravity as a function of fuselage angle of attack.

The preceding discussion shows that the variation of moment about the center of gravity with angle of attack at constant speed for the helicopter rotor would be as shown in Fig. 7. This figure shows that the rotor is unstable with fuselage angle of attack and that a given change in angle of attack from trim produces a greater moment change in the nose-up direction than in the nose-down direction. The figure also shows that the instability with angle of attack becomes greater with larger nose-up angle-of-attack changes and smaller with larger nose-down angle-of-attack changes.

The variation of moment due to changes in fuselage angle is a measure of static stability with angle of attack, which may be expressed mathematically as $\Delta M/\Delta\alpha$ or M_α. For the statically unstable helicopter rotor, M_α is, according to the sign convention, always positive in sign. The variation in thrust with angle change is expressed mathematically as $\Delta T/\Delta\alpha$ or T_α. For the conventional helicopter rotor, T_α is positive.

Evaluation of Static Stability

It has just been shown that, in contrast with the airplane, two aspects of static stability must be considered. Thus, flight measurements of helicopter stick position versus speed are not adequate. Almost every conventional helicopter shows a stable variation of stick position with speed. This stable variation means that the helicopter is stable with speed, but it gives no indication of whether or not it is stable with angle of attack. Actually, most conventional helicopters are unstable with angle of attack, which, according to reference 2, is

a major flying-quality deficiency. Thus, it is apparent that additional measurements are required to determine whether or not a helicopter is stable with angle of attack. One technique used by the N.A.C.A. for making such measurements in flight consists of measuring the variation of stick position with thrust coefficient at constant tip-speed ratio and collective pitch.

Helicopter Stability with Speed and Angle of Attack

For the actual helicopter, the fuselage and stabilizing surfaces (if any) will also contribute aerodynamic moments that vary when either the speed or angle of attack is changed. These moments are brought about in three different ways:

(1) Effect of a variation of moment coefficient with angle of attack. The conventional helicopter fuselage has an unstable variation of moment with angle of attack which adds to the rotor angle-of-attack instability. A fixed tail surface would contribute a stabilizing variation of moment with angle of attack.

(2) Effect of a constant moment coefficient during steady flight on stability with speed. The conventional helicopter fuselage has a nose-down moment coefficient during steady flight. Thus, if the speed of the helicopter is varied from trim at constant angle of attack, the resulting variation in moment arising from the change in dynamic pressure is destabilizing. If stabilizing surfaces contribute a nose-up moment in steady flight by carrying a down load, the resulting variation of moment with speed will be stabilizing.

(3) Effect on stability with angle of attack of a thrust axis offset from the helicopter center of gravity. The thrust axis is offset from the helicopter center of gravity during steady flight either (a) in order to compensate for an aerodynamic pitching moment acting on the fuselage or stabilizing surfaces or (b) if the helicopter has offset flapping hinges and the center of gravity is not on the rotor shaft. The conventional helicopter fuselage has a nose-down moment in steady flight which is compensated for by the thrust vector being offset ahead of the helicopter center of gravity. This offset results in the rotor contributing an additional unstable moment variation with angle-of-attack change as can be understood by examining Fig. 8. An increase in the fuselage angle of attack results in a nose-up rotor moment greater by an amount equal to the product of the thrust increment and the initial center-of-gravity offset than the moment produced by the rotor with no center-of-gravity offset. Thus, nose-down fuselage moments, which require the thrust axis to be offset forward of the center of gravity, add to the angle-of-attack instability of the rotor. If stabilizing surfaces contribute a nose-up moment in steady flight by carrying a down load, the resulting offset between the thrust vector and the helicopter center of gravity counteracts the rotor instability with angle of attack or, if the offset is great enough, will even make the helicopter rotor statically stable with angle of attack. Offset flapping hinges can make a similar contribution to rotor static stability with angle of attack. For example, if the center of gravity is forward of the rotor shaft, then, because of the offset hinges, the center of gravity will also be forward of the thrust vector. Hence, as for the case of a down load on a tail surface, the rotor instability with angle of attack is counteracted.

For the special case of no moment contribution by the fuselage or tail surface and no offset hinges, a center-of-gravity change at a given flight condition results in a change in fuselage attitude which is compensated for by a change in stick position, and the stability of the aircraft is unaffected.* If, however, either the fuselage or a fixed tail surface do contribute moments that change with angle of attack or if the helicopter has offset flapping hinges, a center-of- gravity change will change the horizontal distance between the thrust vector and the center of gravity in trimmed flight. As discussed previously, this change in center-of-gravity offset during trimmed flight does affect the stability of the helicopter.†

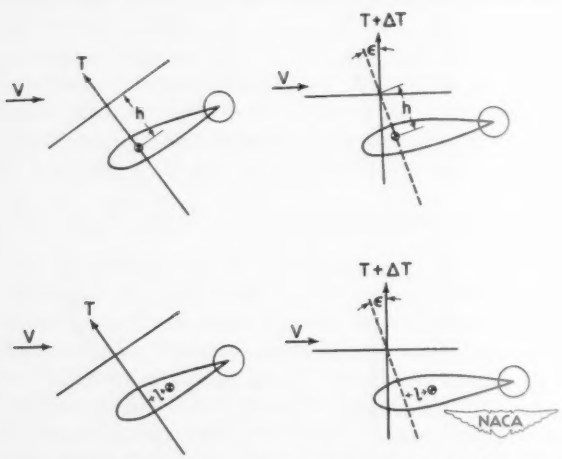

FIG. 8. Effect of center-of-gravity offset on pitching moment arising from fuselage angle-of-attack change. (a, *top*) No center-of-gravity offset. (b, *bottom*) Center-of-gravity offset aft of thrust vector.

CONCLUDING REMARKS

An explanation has been made in terms of fundamental physical quantities of those stability and control parameters that have a primary influence on helicopter flying qualities. The means of rotor control and the source of rotor damping, the two quantities that together determine an important handling characteristic—control sensitivity—have been discussed. The design factors that affect control sensitivity were explained, and it was shown that excessive control sensi-

* For a given flight condition, the attitude of the rotor plane in space is fixed. Thus, in order to maintain a given flight condition when the center of gravity is shifted and a tilt of the fuselage and rotor plane results, the control stick must be moved to a position such that the rotor plane returns to its initial attitude.

† A discussion of the effects of helicopter stability with speed and angle of attack on the dynamic stability of the helicopter is given in reference 5.

tivity would tend to be a problem with smaller helicopters. Static stability with speed and with angle of attack have also been explained, and it was shown that both aspects must be considered for a correct evaluation of the flying qualities of the helicopter.

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[5] Gessow, Alfred, and Amer, Kenneth B., *An Introduction to the Physical Aspects of Helicopter Stability*, N.A.C.A. T.N. No. 1982, November, 1949.

Propeller Turbines in Transport Aircraft

(*Continued from page 17*)

ready reached this mark and are working on further extension.

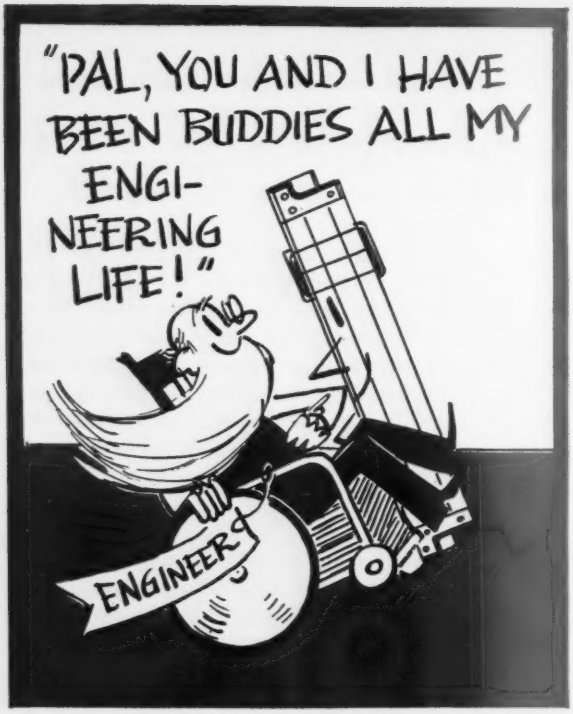
Line maintenance on jet engines is already lower than that for piston engines because of the lack of troublesome items like spark plugs, magnetos, carburetors, etc. Propeller controls are now the biggest item likely to require line attention, and it is hoped that a reasonable amount of service history on the new military models with the T-40 will cut deeply into the many bugs currently present. On the air-frame maintenance side of the picture, the British have already claimed cuts in airplane maintenance by more than half because of the absence of vibration on high-pressure tubing joints, electrical connections, and electronic and miscellaneous other gear.

(3) Cost of spares the same. This acts in direct relationship to the previous item but may be a bit optimistic.

(4) Fuel costs of 12 to 14 cents per gallon, considering the use of Kerosene or ANF-58. The higher heat content of Kerosene adds to the economy as compared to the use of gasoline at 20 cents per gallon. Indications are that Kerosene is by far the most economical fuel, and, if the predictions here are borne out, the savings accomplished will justify the logistics of proper fuel supply.

It will be noted that for extremely short ranges, the turbine-powered 240 is superior to the currently used airplane, with the fuel consumption crossover occurring at a range of about 400 miles for the worst case. It will also be noted that a substantial gain takes place when the lower price fuels are used. ANF-58 fuel gives roughly the same operating cost as Kerosene, but use of Kerosene substantially extends the range of the aircraft. It should be noted at this point that the 240 was designed for most economical operation, at a range of about 400 miles. Stage lengths of domestic lines using this airplane are actually less than half of this. At a range of 200 miles (the condition under which the airplane is in use), the potential advantages of the propeller turbine for the air-line operator are apparent.

This summer will see the flight of the first American turbine-powered transport (Turboliner—see photograph used as heading in this article), to mark a milestone on the road from research to actuality. The American-made turbine that will power this airplane will surpass any flight engine in the world for power to weight ratio and for low fuel consumption. American turbine development, allowed to progress, is yielding successful and satisfactory power plants for both military and civil aviation. The Convair 240 is but one modern air frame capable of gaining higher operational returns through propeller-turbine power. The recent press releases indicate that at least three other major air-frame manufacturers have concrete plans in their programs for propeller turbines. Other engine manufacturers have propeller turbines either on the test stand or in the design state which will figure in future designs. The propeller-turbine-powered transport will become a permanent category of aircraft for short-range operations and will demand a high degree of competition to be displaced in long-range operations by jet propulsion.



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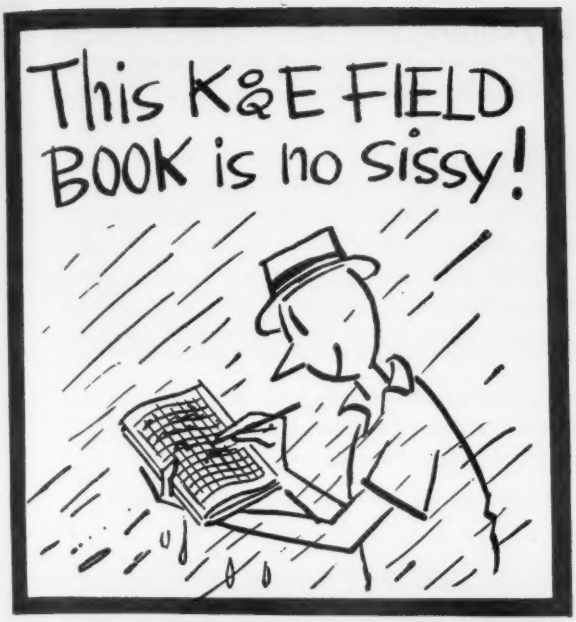

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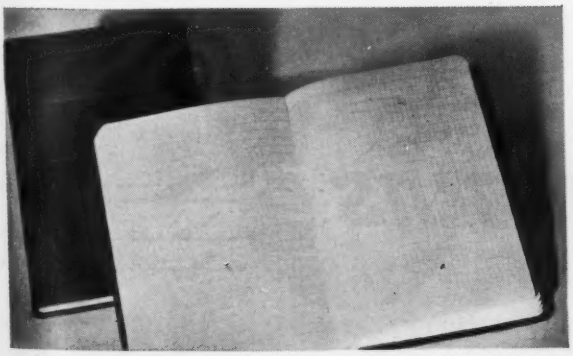

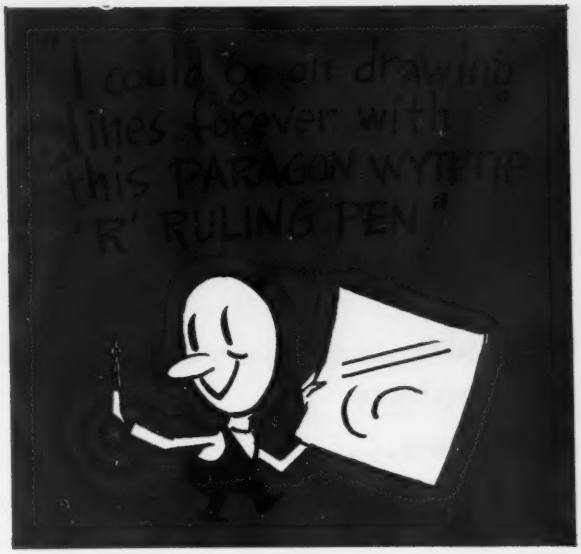

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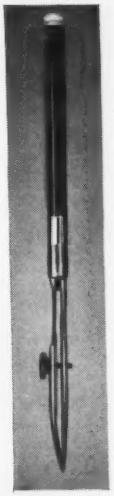

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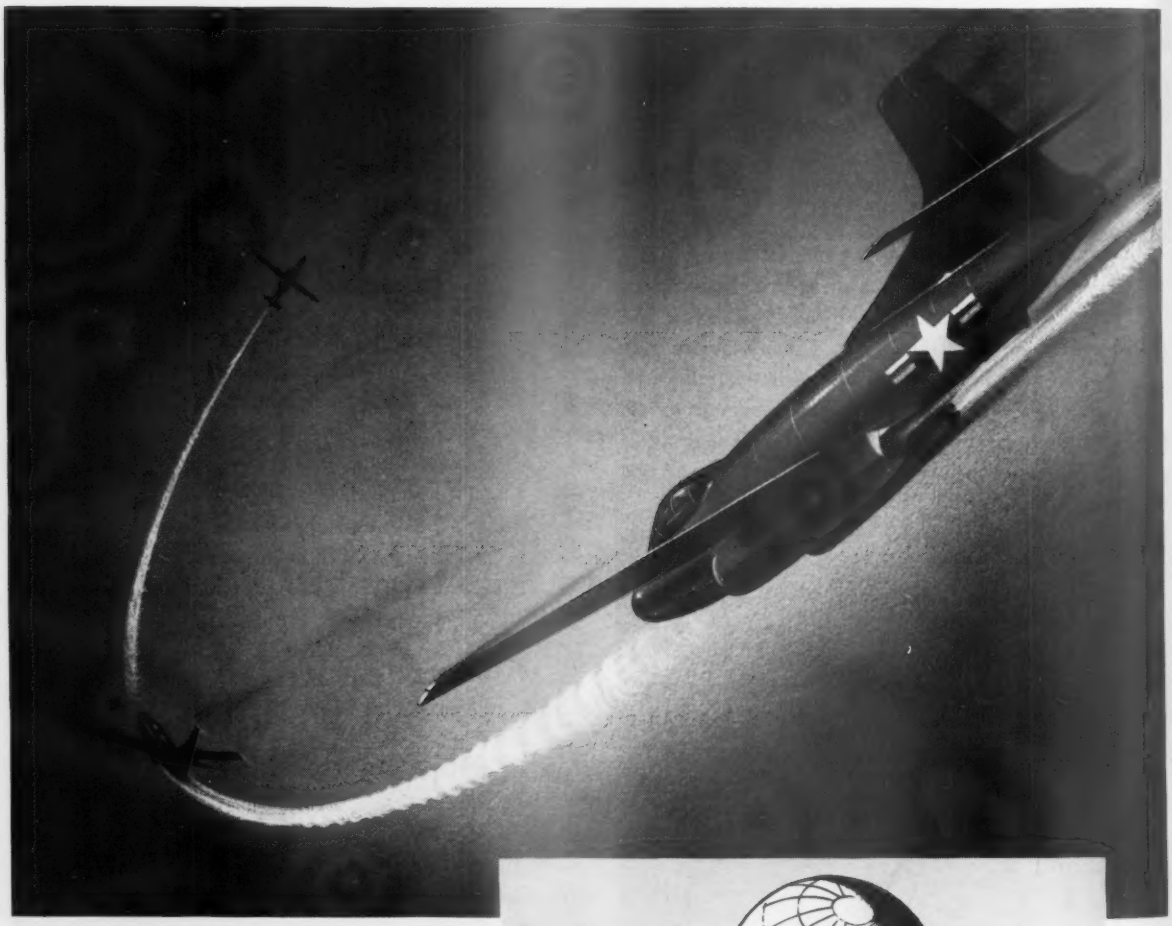

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Linearized Treatment of Supersonic Flow Through Axi-Symmetric Ducts with Prescribed Wall Contours

By

Charles E. Mack, Jr., and Ignace I. Kolodner

Grumman Aircraft Engineering Corporation and New York University

The boundary value problem of supersonic flow through axi-symmetric ducts is solved in this paper on the basis of the linearized theory, and, in particular, the velocity and pressure fields inside the duct are obtained for specified wall contours. The emphasis is on the presentation of the solution in a form suitable for numerical computations, but extensive discussion of the problem is presented.

The solution is obtained by two different methods. The first method involves a suitable distribution of sources and sinks on the surface of a skeleton cylinder whose radius is equal to that of the duct entrance. The second method consists of a direct application of the Laplace transformation to the differential equation describing the flow and yields the solution of the problem in the form of Fourier-Bessel expansions; the expansions thus obtained are summed approximately.

The advantages and disadvantages of the two methods are discussed at length in the concluding part of the paper. Although a thorough mathematical analysis of the problem, necessary in order to bring the program to a successful completion, has been carried out, mathematical considerations of more involved nature are here only glossed over, lest they obscure the ultimate aim of the paper.

Importance of Extending Nyquist Servomechanism Analysis to Include Transient Response

By

R. L. Johnson and J. B. Rea

Douglas Aircraft Company, Inc.

This article stresses the importance of extending the Nyquist servomechanism analysis to include the transient response and points out one method of obtaining the transient response from the conventional frequency response data which is usually the end point of the Nyquist analysis.

The basis for the present "rules of thumb" (phase and gain margins) used when only frequency data are considered is reviewed briefly by comparing the characteristics of a simple feedback servomechanism with those of a linear second-order system. It is shown that, although these rules are pointed toward obtaining a good transient response by considering the system frequency characteristics, they are often inadequate. Once this is realized, the value of actually obtaining the transient response is apparent.

The method outlined for obtaining the transient response to a given input consists of representing the input as a Fourier series, operating on the series with the system transfer function, and summing the resulting series. Response to a step input is given as an example, and the necessary procedure for carrying out the analysis is given and discussed.

Lateral-Control Devices Suitable for Use with Full-Span Flaps

By

Francis M. Rogallo, John G. Lowry, and Jack Fischel

Langley Aeronautical Laboratory, N.A.C.A.

A brief history of the development of lateral-control devices suitable for use with full-span flaps is presented with special emphasis on spoiler-type controls. Recent data on the performance of spoiler-type controls on unswept wings at high subsonic speeds and a limited discussion of spoiler controls on swept wings are included. The several advantages shown for spoiler-type controls—high lift through the use of full-span flaps, good aileron effectiveness throughout the speed range, good yawing-moment characteristics, low-wing torsional loads, and the possibility of low control forces—appear to warrant their consideration for use on all types of airplanes.

Application of spoiler ailerons as air brakes while simultaneously functioning as ailerons is discussed, and their performance is shown to compare favorably with that of other currently used air brakes.

A Study of the Response of an Airplane Landing Gear Using the Differential Analyzer

By

Walter C. Hurty

University of California at Los Angeles

The response of a conventional airplane landing gear is studied by deriving and solving the differential equations of motion for the system. The resistance of the air-oil shock strut depends upon an orifice damping coefficient and an exponent, γ, which determines the air pressure as a function of volume. A study of experimental "drop test" results on similar systems is made to determine these constants. The nonlinear equations of motion are solved by means of the differential analyzer for (1) the landing condition as simulated by a drop test and (2) the taxiing condition in which a periodic ground contour function is assumed. The differential analyzer solutions for the landing condition are compared with drop-test results on the same system.

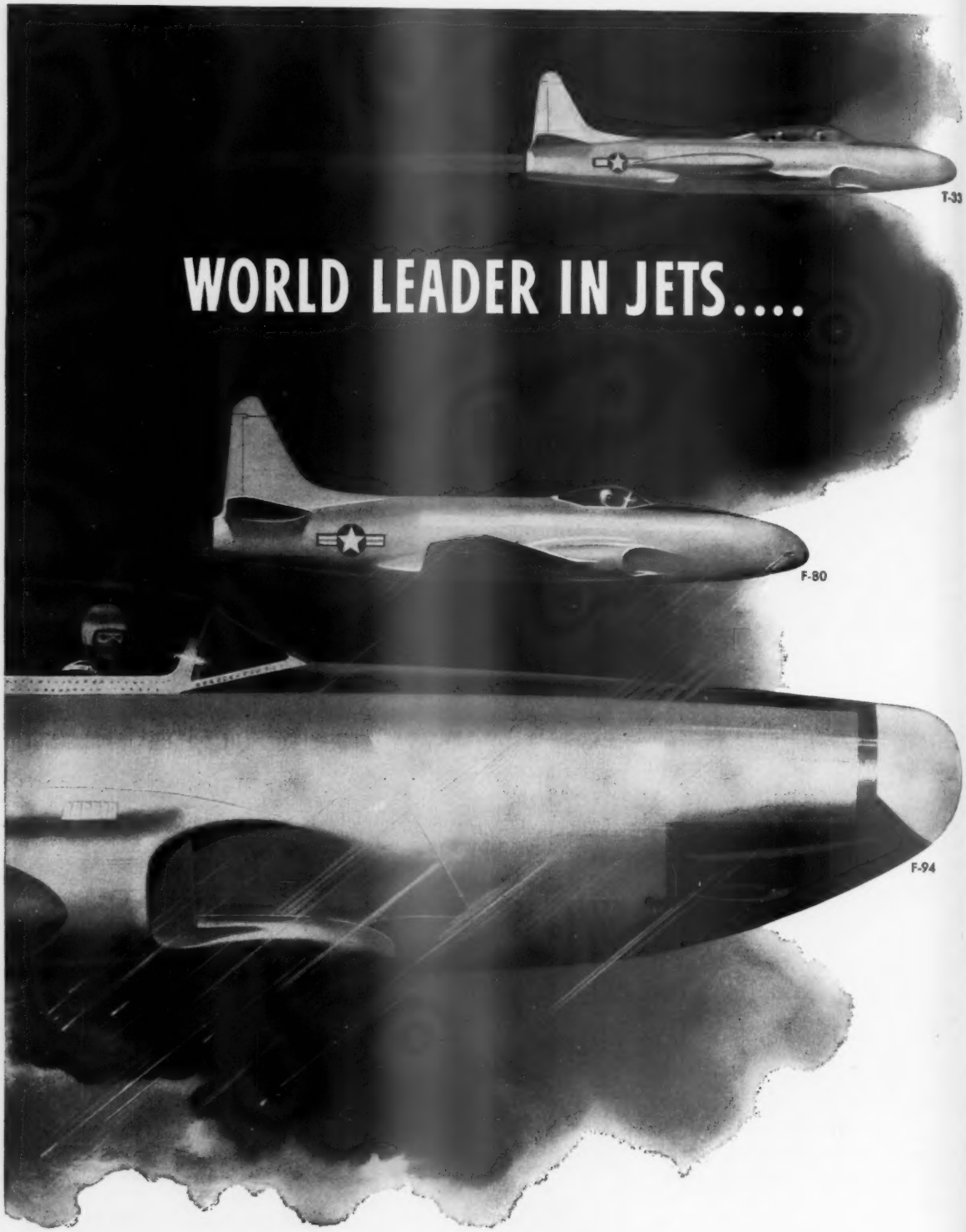
Approximate Solution of Compressible Fluid-Flow Problems by Galerkin's Method

By

Chi-Teh Wang and R. F. Brodsky

New York University

The Galerkin's method has been used in the literature for the approximate solution of elasticity and vibration problems. In this paper its application to compressible fluid-flow problems is carried out. It is found that for compressible flow problems,



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Galerkin's method has two advantages over the Rayleigh-Ritz method, which was previously worked out by one of the authors. First, it is not necessary to formulate variational integrals for various new problems; therefore, these problems can be treated without any mathematical difficulties. Second, there is no restriction on the value of the ratio of specific heats, γ, to be used, a fact that is necessary in the discussion of some irrotational flow problems. The nonlinear problem of compressible flow passing a circular cylinder is carried out as a numerical example. The results are found to be in good agreement with other methods. An extension of Galerkin's method to the general case of flow passing arbitrary bodies is briefly indicated. For these irrotational flow problems, however, Galerkin's method seems to suffer the disadvantage of requiring more work in carrying it out than the Rayleigh-Ritz method. The application of the Galerkin's method to laminar boundary-layer problems is discussed, and the boundary-layer problem of a compressible flow past a flat plate is formulated. A numerical example is carried out to illustrate the method.

An Extension of the Theory of the One-Dimensional Shock-Wave Structure

By

Leonard Meyerhoff

Polytechnic Institute of Brooklyn

This paper presents the method and results of an analytical investigation of the flow inside a shock wave in a steady one-dimensional flow. Two categories are treated: The first considers the problem for constant gas properties, while the second is concerned with the influence of specific heat, conductivity, and viscosity, dependent on temperature.

For the problem with constant gas properties, numerical solutions are given which show that there must be an infinite number of shock-wave-type solutions. Only one of these solutions terminates in a region of uniform flow with the values of Rankine-Hugoniot. These solutions, obtained partly by differential analyzer and partly by hand, are given for initial Prandtl Numbers, $P_r \equiv c_p\mu/k$, of 0.75 (T = 0°C.) and 0.657 (T = 500°C.). A comparison shows that the shock-wave thickness for an initial Mach Number of 2.0 is about three times greater for $P_r = 0.657$ than for $P_r = 0.75$.

For the problem with temperature-dependent gas properties, the method and results are shown in detail for the case of uniform exit flow. It was necessary to calculate the change in the limit values of Rankine-Hugoniot because of variable gas properties in order to perform the required numerical integrations. The temperature variations used for c_v, μ, and k correspond to experimental data. A nu-

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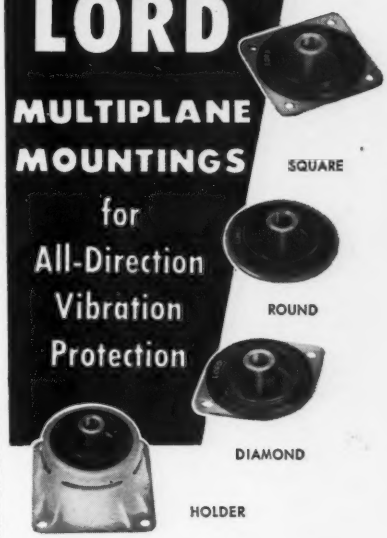

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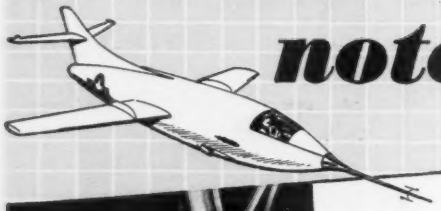

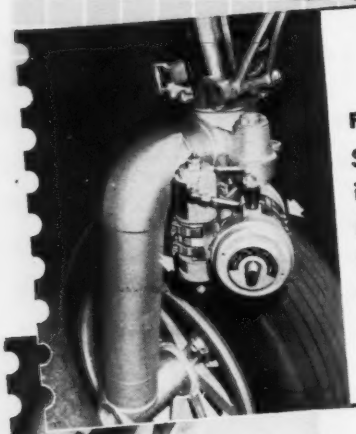

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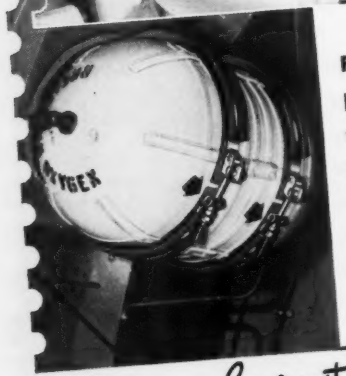

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merical example, given for an initial Mach Number of 4.0, shows that the shock-wave thickness is approximately two and one-half times greater than that for constant gas properties; it is about two and one-half times greater than the mean free molecular path.

Nonlinear Effects of Structural Deformation on Stability

By

Albert Epstein

Republic Aviation Corporation

An analysis is made of the effect of skin buckling on longitudinal stability and the influence of such effect on control forces. Buckling alters aeroelastic characteristics by the reduction of torsional rigidity in the case of an unswept wing and by the reduction of both bending and torsional rigidity in the case of a swept wing. It can also precipitate flow separation, which affects pitching moments. Since buckling commonly occurs under the higher load factor conditions, large changes in the slope of the lines of stick force versus load factor may be the consequence. The flow separation appears to have the predominant influence on such slope changes. Test data of a current fighter airplane are used for illustration.

Mention is made of the effect of a variable modulus of elasticity on the rate of structural deformation and of the effect of bending deflection on the camber of a swept-wing section.

The Transient Temperature Distribution in a Wing Flying at Supersonic Speeds

By

Joseph Kaye

Massachusetts Institute of Technology

The motion of a vehicle at high supersonic speeds results in a large nonuniform temperature rise within the vehicle. Several new problems, such as the magnitudes of the thermal stresses and of the aerodynamic deflections caused by this nonuniform temperature distribution, must be solved by the designer. These problems depend, in turn, on accurate prediction of this transient temperature distribution.

The calculation of the transient temperature distribution is illustrated for the case of a thin wedge-shaped wing or airfoil subjected to constant acceleration from Mach Numbers of 1.4 to 6. The calculation depends strongly on the state of the art relative to heat transfer at supersonic speeds; as a result, the calculations may be systematically in error because of the lack of data in this art.

A long and laborious numerical method of solution of the differential equation for

heat flow in two dimensions with boundary conditions dependent on time is presented, and the resultant temperature distributions in the wing are given in chart form. In this solution the spanwise heat flow is assumed to be negligible. The results indicated that the heat-flow problem could be reduced to one-dimensional heat flow in the direction normal to the chord without sacrifice of accuracy for a wing with a maximum thickness ratio of less than 10 per cent.

A shorter numerical method of solution of the differential equation for heat flow in one dimension—normal to the chord—is presented. It is shown that this method yields temperature distributions that are in excellent agreement with those calculated by the method for two-dimensional heat flow. This shorter method was to investigate the effects of changes in the coefficients of heat transfer and in the values of the acceleration. It is shown that this shorter numerical method of solution is applicable to the general case of a thin airfoil, provided the variation of the local coefficient of heat transfer with time is available.

The Characteristics of Supersonic Wings Having Biconvex Sections

By

Beverly Beane
United Aircraft Corporation

The wave drags of a representative series of thin, tapered plan-form wings having multislope surfaces approximating the circular arc or biconvex section are computed by means of a generalization of the linear source-sink solution of "Supersonic Wave Drag of Thin Airfoils," by A. E. Puckett (JOURNAL OF THE AERONAUTICAL SCIENCES, Vol. 13, No. 9, p. 475, September, 1946). The computational methods are described, and the results are compared with those of similar wings having double-wedge section. Limited experimental checks of the computed results are included. It is concluded that the linear theory gives a reasonable first-order approximation of the characteristics of biconvex section wings and that for most applications the biconvex section will be superior to the double-wedge section.

Effect of Torsional Stiffness Requirements on Wing Structural Weight

By

W. R. Micks
The RAND Corporation

Curves are obtained which show the total increase in weight of an optimum-designed sheet-stiffener compression panel when the skin thickness is increased by an arbitrary amount. These example curves are based on data from tests conducted by the N.A.C.A. on 75S-T Y-stiffened panels. However, the method outlined may be applied also to the plotting of other sheet-stiffener compression panel data.

The N.A.C.A. data, when put in the form outlined here, indicate the minimum amount by which the total weight of sheet and stiffeners would be increased in order to achieve a given increase in sheet thickness. If optimum design principles are followed, this increase in total weight is considerably less than the increase that would result if the amount of stiffener material is left unchanged.

The method outlined here for presenting data is of particular use in preliminary design work where the effects of aeroelasticity requirements must be evaluated in terms of increased wing weight.

A Flexible Nozzle for a Small Supersonic Wind Tunnel

By

Satish Dhawan and Anatol Roshko
California Institute of Technology

The design of a small supersonic wind-tunnel test section (4 by 10 in.) incorporating a flexible nozzle is outlined. The flexible nozzle consists of a high-strength stepped steel plate. Two screw jacks provide an easy means of continuously changing the nozzle's shape according to the aerodynamic requirements. The boundary-layer compensation can also be varied during operation. Pressure surveys, together with schlieren and interferometric analysis of the test section, show the flow to be uniform over the operating range (M = 1.1 to 1.5).

Gust Loads on Rigid Airplanes with Pitching Neglected

By

R. L. Bisplinghoff, G. Isakson, and T. F. O'Brien
Massachusetts Institute of Technology

The motion of a rigid airplane flying into a linearly graded gust is analyzed. The pitching motion of the airplane is neglected, but unsteady aerodynamic effects are taken into account. The analysis is first carried out assuming incompressible flow. The equation of motion is solved by application of the Laplace transformation. The solution is expressed in the form of an alleviation factor and is found to depend upon two nondimensional parameters, one being the so-called mass parameter and the other relating the gust gradient distance to the airplane chord. Comprehensive data on the alleviation factor are presented for a practical range of values of the mass parameter and the gradient distance. The case of flight at high subsonic speeds is considered, and it is found that an analysis of this case is not immediately practical, since a great deal of basic numerical data on the aerodynamic forces is required and little of these data has yet been computed. On the other hand, it is found that the case of supersonic flight may be readily analyzed, and this is done, under the assumption of two-dimensional flow, for flight through a sharp-edged gust. Alleviation factor data are presented for a number of values of the Mach Number and for a practical range of values of the relative density parameter. It is shown that gust alleviation due to unsteady flow is likely to be slight for any practical supersonic airplane.

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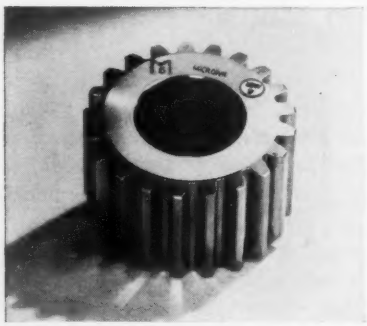

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Aerodynamics (2)

BOUNDARY LAYER

The Incompressible Boundary Layer with Pressure Gradient and Suction. Leon Trilling. *Journal of the Aeronautical Sciences*, Vol. 17, No. 6, June, 1950, pp. 335–342, illus. 28 references.

Comparison of Theoretical and Experimental Heat Transfer on a Cooled 20° Cone with a Laminar Boundary Layer at a Mach Number of 2.02. Richard Scherrer and Forrest E. Gowen. *U.S., N.A.C.A., Technical Note No. 2087*, May, 1950, 20 pp., illus.

The Solution of the Laminar-Boundary-Layer Equation for the Flat Plate for Velocity and Temperature Fields for Variable Physical Properties and for the Diffusion Field at High Concentration. H. Schuh. (*ZWB/FB/1980*, August 18, 1944.) *U.S., N.A.C.A., Technical Memorandum No. 1275*, May, 1950. 19 pp., illus. 11 references.

Specific Aerodynamic and Propulsion Problems. I—Some Prandtl Number Effects on the Transfer of Heat. Arthur N. Tifford. *Ohio, State University, Engineering Experiment Station News*, Vol. 22, No. 1, February, 1950, pp. 11, 12, 30–34, illus.

Calcul du Coefficient de Convection à la Surface d'un Profil Cylindrique. M. Vasseur. *La Recherche Aéronautique*, No. 14, March-April, 1950, pp. 17–23, illus. 4 references.

FLUID MECHANICS & AERODYNAMIC THEORY

A Relation Between Time-Dependent and Steady Linearized Supersonic Flows Past Conical Bodies. C. Gardner. *Communications on Pure and Applied Mathematics*, Vol. 3, No. 1, March, 1950, pp. 39–43.

The time-dependent problem that arises in linearized supersonic flow past a conical surface that is continually deforming or oscillating and which is entirely within the Mach cone at its vertex is equivalent to the steady-state problem. The value of the solution of the velocity potential at a given point and at a given time is equal in value to the function that satisfies the equation of steady supersonic flow and whose normal derivative at the surface has a value that can be expressed as a certain integral transform of the given boundary values.

The Flow Behind a Stationary Shock. M. J. Lighthill. *The Philosophical Magazine*, Vol. 40, No. 301, February, 1949, pp. 214–220.

A linearized equation of the steady inviscid adiabatic flow of a gas, not assumed perfect, isentropic, or isenergetic, is given in a simple form. It is used to study the bending of the bow shock on a supersonic airfoil due to the incidence of waves from the surface, without assuming that the shock strength is small. The waves are shown to be reflected back along the characteristics, and figures for the reflection coefficient are obtained. For a thin supersonic airfoil, the method is used to discuss the entropy boundary layer due to inexact leading edge sharpness.

The Flow of Viscous Fluids Round Plane Obstacles. R. Roscoe. *The Philosophical Magazine*, Vol. 40, No. 302, March, 1949, pp. 338–351, illus. 8 references.

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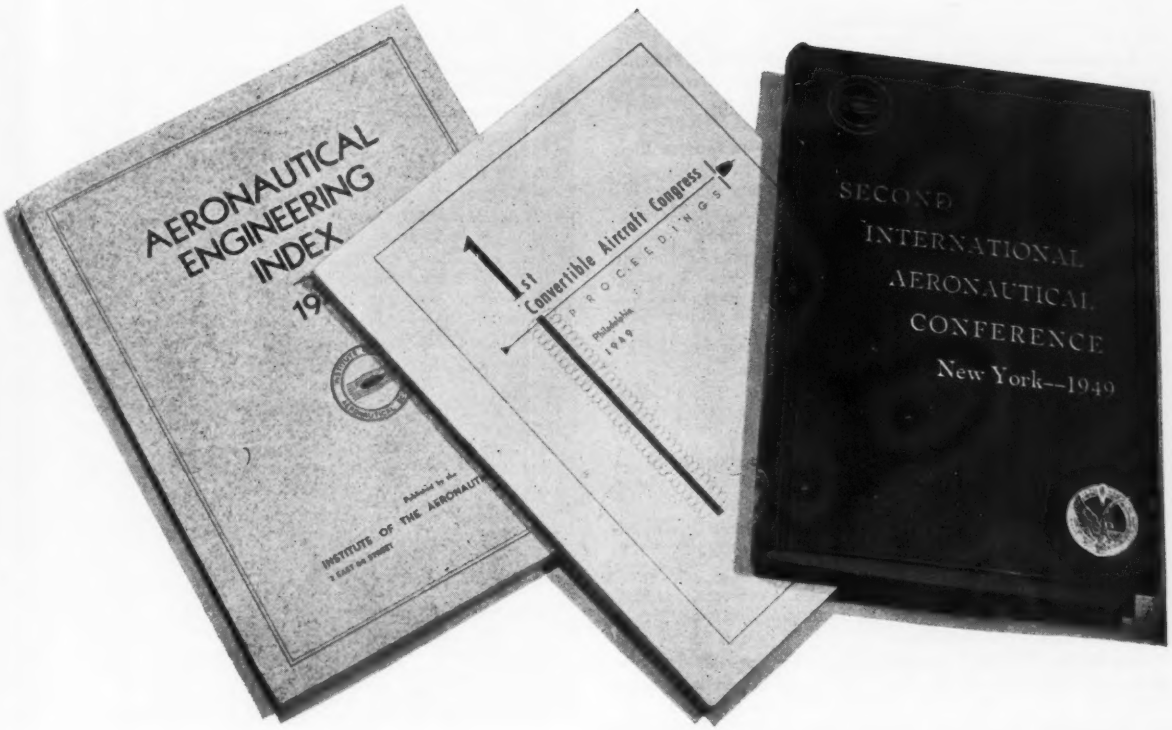

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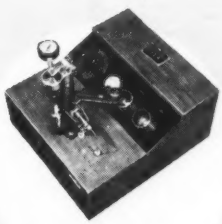
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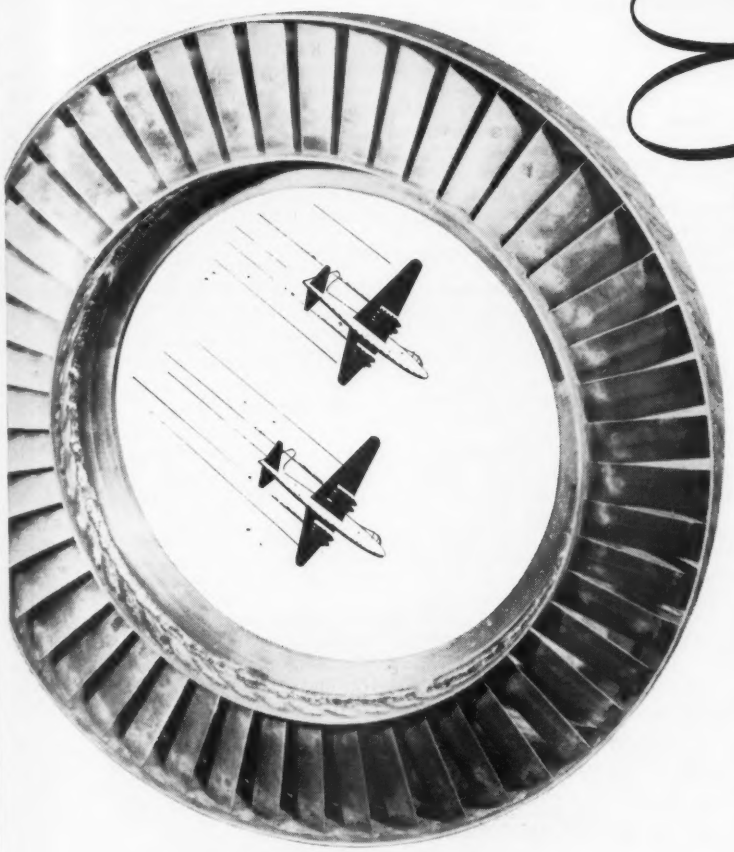

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Aeronautical Reviews — BOOKS

Supersonic Aerodynamics

By Edward R. C. Miles. New York, McGraw-Hill Book Company, Inc., 1950. 255 pp., illus., tables, diagrs. $4.00.

Supersonic Aerodynamics, by Edward R. C. Miles, is a theoretical introduction to the supersonic domain which has been rendered outstanding by the unprecedented scope of its contents. The clarity and simplicity with which it is presented will bring much satisfaction to the senior and first-year graduate student to whom it is addressed.

The author is Research Mathematician with the Institute for Cooperative Research and Lecturer in the School of Engineering at The Johns Hopkins University. The text is the logical result of his experience as a teacher and as a scientific investigator and reflects the insight gained in both pursuits.

It is the author's fundamental conviction to use mathematics, no matter how difficult, as an ally. Thus, as each new subject is introduced, the necessary mathematical background is simultaneously prepared. To supplement this exposition, Miles never fails to include a numerical example and a selection of highly instructive problems whose solutions are usually given. In this manner vector analysis, numerical and graphical integration methods, elements of potential and function theory, determinants, characteristic lines, and equation analysis are covered.

It is equally obvious that Miles has given much thought to the style and order of presentation. Each chapter is an entity in itself, containing both the two- and three-dimensional phenomena in the suitable coordinate systems. The logical continuity of the subject material makes the work extremely readable.

A notable innovation is the inclusion of an entire chapter devoted to the full explanation of divergence and circulation. The demonstration of the applicability of the Helmholtz laws in compressible flow is particularly noteworthy.

Throughout, the method of characteristics is handled by a painstaking step-by-step process that leaves nothing to doubt. Similar care is taken with the traditional Taylor-Maccoll cone solutions. However, it is important to note that only axial symmetric cases are treated in the three-dimensional realm.

The final chapter, a comparison of adiabatic and shock flow, contains a great deal of elusive information. Here, Miles considers the changes of pressure and velocity effected by a temporary deflection of a supersonic stream and examines the existence of adiabatic compressions at high speeds.

Despite the general excellence of the text, there are several criticisms that seem pertinent, such as a certain lack of sophistication, which will be particularly felt by graduate students. For instance, in the early sections, the author sometimes prefers numerical, rather than analytic, proofs. The substitution of numbers for symbols also exemplifies a type of handbook engineering that Miles specifically states he is trying to avoid.

While the mathematical preparation is more than adequate, the basic underlying theory is neglected. As a result, the reader receives a highly specialized point of view and has no insight into the beauty of the solutions, which often seem to be picked out of thin air. Consequently, applications to any but the immediate problems discussed would be difficult.

The notation is usually self-explanatory and in conformity with professional practice. However, it does get a little involved in the shock chapters, where special substitutions becloud real meanings. Fundamental examinations of wind-tunnel design and experimental measurement devices and theory are entirely omitted. Finally, the treatment of hodograph solutions is at best cursory, no true summarization of the boundary problems being indicated.

In deference to Mr. Miles, some of these criticisms are not applicable if the educational status of his intended audience is considered.

Supersonic Aerodynamics has undoubtedly filled a vital gap. The way is now clear to the organizer of a course in supersonics. If but one term is allotted, Miles' text will unquestionably serve perfectly. If a whole semester is available, a preliminary text, such as Liepmann and Puckett, followed by an advanced book, like Ferri, is the recommended procedure.

ROBERT F. BRODSKY
Instructor, Mechanical Engineering Department
New York University

The Organization of Industrial Scientific Research

By C. E. Kenneth Mees and John A. Leermakers. Revised 2nd Ed. New York, McGraw-Hill Book Company, Inc., 1950. 383 pp., figs. $5.00.

Dr. Mees and Dr. Leermakers have produced an exhaustive treatment of a rather difficult subject and managed to maintain a readable and interesting style of writing at the same time.

Aviation is in many respects almost unique in that the industry, during most of its existence, has been primarily a large research and development group with relatively minor emphasis on manufacturing and sales, in contrast with most other fields where the commercial development has generally preceded and made possible the large-scale introduction of research and development methods. Nevertheless, aeronautical engineers and research people will recognize many familiar situations as they are described in this book, and I, for one, have found little to criticize in the philosophy expounded by the authors.

The early part of the book deals with the historical evolution of the scientific attitude and later with the development of methods of organization. This is followed by a general discussion of industrial research in which the relation of the scientific approach to industrial problems and the objectives of research laboratories are analyzed in a general way.

The second part of the book deals with the agencies for the conduct of industrial research and contains chapters on government laboratories, associations for industrial research, and some large industrial laboratories. The chapter on government labora-

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tories contains a brief description of the major laboratories in the United States, England, and the British Empire, and some of those extant in Germany before World War II.

In the chapter on associations for industrial research, the authors break these associations down into the three categories: consulting laboratories, cooperative laboratories, and technological research institutes. A few of the principal associations and laboratories of this type are described in this chapter.

The chapter on technological research institutes pertains primarily to descriptions of the Mellon Institute, the Battelle Memorial Institute, the Armour Research Foundation, and several smaller institutions.

In the chapter on some large industrial laboratories, a description is given of the Bell Telephone Laboratories, the Standard Oil Development Company, the Gulf Research and Development Company, the general laboratories of the U.S. Rubber Company, the General Electric and Westinghouse laboratories, a number of chemical laboratories, and the Kodak Research Laboratory.

Part III discusses in a great deal of detail the relation of the laboratory to the other divisions of industrial companies, the organization of the laboratory, selection of the staff and the research program, as well as such subjects as financial administration, reports, patents, publications, libraries, and details of the operation of technical laboratories.

While the whole book is thoroughly developed, Part I is inherently of more universal interest since the specific problems covered in the latter part of the book are necessarily somewhat different for each situation.

FRANK W. CALDWELL
Director of Research
United Aircraft Corporation

An Introduction to the Aerodynamics of the Airplane (Part 2)

By H. Serbin. 2nd Ed. West Lafayette, Ind., The Rose Company, 1949. Various paging, diagrs. Mimeographed. $6.10.

The intended scope of this book is indicated by the following chapter titles: Chapter 1, Similarity. Chapter 2, Airfoils of Finite Span. Chapter 3, Static Stability and Control. Chapter 4, Dynamic Stability of the Airplane. Appendix 1, Fourier Series and Harmonic Analysis. Appendix 2, The Solution of Linear Homogeneous Differential Equations.

Since Part 1 has not yet appeared, and since there is no introduction to Part 2, it must be assumed that the necessary prerequisites, such as two-dimensional airfoil theory, are included in a preceding course.

The treatment of similarity is clear and straightforward, presenting a sufficient background for the following

material but avoiding lengthy and formal discussions.

The chapter on airfoils of finite span dominates the book and constitutes about one-half of the total. On the whole, the author has done an efficient job of organizing the large amount of available material, at least as far as incompressible flow is concerned. However, only two pages are devoted to the question of compressibility effects in both the subsonic and supersonic régimes, and no attempt is made to describe any of the fundamental physical phenomena that are involved. The derivation of the compressibility correction to the lift curve slope for an elliptic wing, based on the *two-dimensional* Prandtl-Glauert law is, in the reviewer's opinion, incorrect, despite the fact that the end result is in agreement with the result that would have been obtained by the correct application of the Prandtl-Glauert transformation to the three-dimensional problem. In the discussion of sweepback effects, both the arguments and the results are incorrect, at least for the lift reduction, the primary difficulty being the author's failure to include the effect of spanwise flow when the wing is given an incidence by rotating it about the pitch axis (as opposed to a swept, spanwise axis).

The treatments of both static and dynamic stability are relatively complete, although little attention is paid to the problem of actually evaluating the stability derivatives. The discussion of the relation between static and dynamic stability is, however, somewhat weak. In particular, the author's statement that dynamic instability, when it occurs, is due to excessive static stability, which causes such a *rapid* restoration toward the equilibrium position that the damping is inadequate, seems completely illogical to the reviewer and certainly fails to emphasize the importance of the presence of more than one degree of freedom with coupling of a nonconservative character. Indeed, in view of this nonconservative character, it is not absolutely correct to state that static stability is a necessary condition for dynamic stability, albeit such is usually the case for practical configurations.

The appendix on Fourier series is commendable in establishing the results through the requirement that a given finite series approximate the function to be represented with a minimum r.m.s. error over the interval of the expansion. The second appendix deals with the solution of ordinary linear differential equations and gives a sketchy introduction to operational methods.

It is the reviewer's opinion that the author's presentation is, on the whole, too concerned with presenting a large range of experimental and empirical data at the expense of emphatic presentation of fundamentals. (The reviewer does not wish to dwell upon such relatively minor matters as typographical errors. These will no doubt be cleared up and the text rewritten where necessary for clarification in any final printed edition.) Nevertheless, if properly supplemented, it should make an excellent reference for a first or second course in engineering aerodynamics.

JOHN W. MILES
Department of Engineering
University of California
at Los Angeles

Book Notes

AERODYNAMICS

L'Écoulement en Conduites des Liquides, Gaz et Vapeurs. Albert Schlag. 2nd Ed. Paris 6, Dunod, 1949. 249 pp., diagrs. 850 Fr.

In this second edition of a book first published in 1933, the section on physical properties of fluids has been enlarged, and the theory of similitude is presented in a new form. Some new formulas, discussions of transportation of gases for great distances and of flow in conduits of noncircular section have been added to the chapter on resistances. The third chapter, on flow measurement, has been entirely revised to account for recent work in standardization, and pulsing flow is briefly discussed. Numerical examples have been added illustrating the methods described. The bibliography has been revised and includes 221 references to books, papers, and standards. The author is a professor at the University of Liége.

AERONAUTICS, GENERAL

Cours d'Aérotechnique. G. Serane. Paris 6, Dunod, 1949. 270 pp., diagrs.

The author's purpose is to present the elementary principles of aerodynamics and the dynamics of the airplane, using only algebra and geometry. Fluid mechanics, wind-tunnel testing, simple bodies in an air stream, the wing, the airplane and special types of aircraft, and propulsion systems take up the first half of the book. Final chapters deal with the mechanics of flight, stability, performance calculation, seaplanes, flying boats, and instruments. The author is in charge of courses of instruction for flying personnel of the air line Air France.

ATOMIC ENERGY

Nuclear Physics; A Course Given by Enrico Fermi at the University of Chicago. Notes Compiled by Jay Orear, A. H. Rosenfeld, and R. A. Schluter. Revised Ed. Chicago, University of Chicago Press, 1950. 246 pp., diagrs. $3.00.

In this revised edition of Dr. Fermi's lectures given in the first part of 1949, corrections and minor revisions have been made on about 70 pages in the first nine chapters, and major revisions have been made in the chapter on cosmic rays. Chapter headings are: Properties of Nuclei, Interaction of Radiation with Matter, Alpha Emission, Beta-Decay, Gamma-Decay, Nuclear Forces, Mesons, Nuclear Reactions, Neutrons, and Cosmic Rays. A brief bibliography and an index of subjects are included.

ELECTRONICS

Antenna Theory and Design. H. Paul Williams. London, Sir Isaac Pitman & Sons, Ltd., 1950. 2 Vols. 142, 522 pp., illus., diagrs. 21*s.*, 63*s.*

The first volume is devoted to theory and design, proceeding from the fundamental laws of electromagnetism through Maxwell's equations to the theory of retarded potentials and radiation from specified current distribution and ending with the theortical treatment of a practical case of an excited metallic body. The second volume, on the electrical design of antennas, is independent of the first as much as possible and includes an introductory nonmathematical discussion of the basis of radiation. Design curves based on a logarithmic scale are used, and there is a separate chapter on propagation. M.K.S. units and the metric system are used as far as possible. A bibliography of 418 books and articles, classified by the subjects of chapters, and author and subject indexes are included. The author is head of the Electronics Department of the Fairey Aviation Company, Ltd.

Fundamentals of Discharge Tube Circuits. V. J. Francis. London, Methuen & Company Ltd.; New York, John Wiley & Sons, Inc., 1948. 134 pp., diagrs. $1.50.

The more fundamental properties of discharge tubes in relation to the circuits in which they can be operated are discussed with emphasis on the principles upon which the design is based. The book is the substance of talks on the electrical properties of discharge devices which were given by the author in 1946. The author is with the Research Laboratories of the General Electric Company, Ltd., Wembley, England.

Frequency Modulation. K. R. Sturley. Brooklyn, N.Y., Chemical Publishing Company, Inc., 1950. 98 pp., diagrs. $4.75.

The general nature of the system is described, in which a radio-frequency wave, acting as a carrier for the direct transmission of speech or music over long distances, has its frequency varied at a suitable rate while its amplitude remains constant. The advantages and disadvantages of frequency-modulated and phase-modulated transmission are examined, and methods of modulating the frequency or phase of a carrier are discussed. The final two-thirds of the book is concerned with the frequency-modulation receiver, frequency-to-amplitude conversion, and the complete receiver. A list of approximate American equivalents of British vacuum tubes is included and is incorporated into a chart of the typical frequency-modulation receiver circuit. The bibliography lists 56 references published between 1922 and 1946. The author is Head of Engineering Training for the British Broadcasting Corporation.

Radiotechnique Aéronautique. E. Fromy. 2nd Ed. Paris 6, Dunod, 1947. 359 pp., diagrs. 720 Fr.

Based upon a course given at L'École Nationale Supérieure de l'Aéronautique, this textbook is designed to provide a knowledge of basic phenomena and principles and to enable the aeronautical engineering student to understand the nature of radio equipment and communications in airplanes. About three-fifths of the book is devoted to a review of electricity and magnetism, alternating current, radio circuits, vacuum tubes, transmission, reception, and the fundamental characteristics of receivers. The final chapters are devoted to the airplane and its radio equipment, including radio noise and shielding, and descriptions of typical installations. Mobile ground stations are briefly described in the closing pages.

Radio-Navigation Aérienne; Réalisations et Perspectives. P. Gaudillere. Paris 6, Dunod, 1949. 245 pp., diagrs. 1,350 Fr.

In the first part, which is 72 pages in length, the subject is outlined methodically and discussed in general terms, covering air navigation, radio, and various ways of applying radio to the problem. In the second part, containing 80 pages, long-range and short-range navigation equipment, landing aids, and remote-controlled flight are discussed, including existing equipment, equipment proposed, and recommendations of the International Civil Aviation Organization. The third part, of 84 pages, takes up the future of radio navigation, describes the necessary qualities of a navigation system, and discusses the localization of aircraft, methods of assistance in flight, anticollision sys-

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tems, and automatic flight. Conclusions and recommendations are given in the concluding seven pages. The author is chief of the radio navigation service of the Philips Laboratories.

MATERIALS

METALS & ALLOYS

Manual on Fatigue Testing. Committee E-9 on Fatigue. (Special Technical Publication No. 91.) Philadelphia, American Society for Testing Materials, 1949. 82 pp., diagrs. $2.50, paper; $3.15, cloth.

Following an introduction and a section on definitions of terms and symbols used in fatigue testing, the discussion takes up fatigue testing machines according to type of load, type of stress, and design and operating characteristics. Specimens and their preparation, with detailed instructions for polishing them, and test procedures and technique, including planning of tests, selection of fatigue machines, selection of samples and preparation, and measuring specimens are next discussed. The final sections deal with the presentation of fatigue data and interpretation of data. Bibliographies include 120 references on testing machines, 44 on test procedures, and a general bibliography of 55 references classified under seven subjects.

Symposium on Deformation of Metals as Related to Forming and Service. (Special Technical Publication No. 87.) Philadelphia, American Society for Testing Materials, 1949. 117 pp., illus., diagrs. $2.00.

Contents: Test of Ductility in Ship Structure, Wendell P. Roop; Notch-Sensitivity of Ship Plate—Correlation of Laboratory-Scale Tests with Large-Scale Plate Tests, Noah A. Kahn and Emil A. Imbembo; Measurement of Ductility in Sheet Metals, John R. Low, Jr., and Thomas A. Prater; Hydraulic Bulge Testing of Sheet Metals, W. T. Lankford; and Notched Bar Tension Tests on Annealed Carbon Steel Specimens of Various Sizes and Contours, M. L. Fried and G. Sachs.

Metal Cleaning Bibliographical Abstracts. Prepared by Jay C. Harris. (Special Technical Publication No. 90.) Philadelphia, American Society for Testing Materials, 1949. 72 pp. $2.75.

Abstracts are presented of 494 references published between 1893 and 1949, including patents of eight countries, with detailed indexes of subjects, authors, specifications, and patent numbers. The arrangement is by years. The compiler is associated with the Monsanto Chemical Company.

METEOROLOGY

The Thunderstorm; Report of the Thunderstorm Project. Washington, U.S. Govt. Printing Office, 1949. 287 pp., illus., diagrs. $2.25.

This is the final report on the present phase of The Thunderstorm Project, directed by Horace R. Byers, a joint project of the Air Force, Navy, N.A.C.A., and The Weather Bureau. The report is based upon observations taken during the summer of 1946 at Orlando, Fla., and in 1947 at Wilmington, Ohio, including missions by five airplanes flying simultaneously at 5,000 to 26,000 feet, which made 1,363 traverses of storms, and 824 rawinsone and 503 rawin soundings at altitudes up to 50,000 feet. Following an introductory section, the first half of the report is concerned with thunderstorm structure and circulation, turbulence and hydrometeors within the thunderstorm, thunderstorm weather near the surface, electric fields within the thunderstorm, data obtained by radar, the effect of environment wind on existing thunderstorms, preferred areas of thunderstorm development, and squall lines. Flight and ground operations in thunderstorm conditions are described briefly, and the last half of the report presents detailed examples of thunderstorms and detailed descriptions of the surface, upper-air and radar equipment, airplane instruments, and photographic equipment used. Lists of 22 published contributions of the project and of 63 references are included.

MILITARY AVIATION

National Air Power and International Politics; A Select Bibliography. Eugene M. Emme. (Air University Documentary Research Study.) Maxwell Air Force Base, Alabama, Department of the Air Force Library, Historical Division, Studies and Research Branch, 1950. 191 pp.

This useful bibliography includes 1,484 references arranged under eight broad subjects and eleven subheadings, with author and subject indexes. Among the topics covered are: aviation as related to world politics; national air power in war, including air power as an independent institution and in relation to land, sea, and psychological warfare; elements of national air power, including the military air force, scientific research and development, the aeronautical industries, and civil and commercial aviation; national air strategy and international organization; and atomic energy, aviation, and international politics.

NAVIGATION

Navigation the Easy Way. Carl D. Lane and John Montgomery. New York, W. W. Norton & Company, Inc., 1949. 126 pp., illus., diagrs. $2.95.

Navigation principles and practices are presented in picture form, and the accompanying text uses addition and subtraction only where mathematics is required. Piloting, dead reckoning, and celestial navigation are covered, with introductory sections on electronic aids to navigation. U.S. Navy and Air Force methods of demonstration are used. There is a combined glossary and index, and lists of navigation equipment that the reader may use with the book and lists of books for more advanced study are supplied.

PRODUCTION

Le Formage des Tôles, et ses Applications à l'Industrie Aéronautique. P. Capdeville. 2nd Ed. Paris 6, Dunod, 1950. 137 pp., diagrs. 430 Fr.

The forming of sheet metal is covered in this textbook for aeronautical engineers, including metal cutting, simple forming operations, heat treating, stamping and pressing, deep drawing, the Guerin process, and recent advances in forming processes. There is a final chapter on types of machine tools and factory layout. The emphasis throughout is upon applications in the manufacture of airplanes. The author is chief engineer of the Ministère de l'Air and a professor at L'École Nationale Supérieure de l'Aéronautique.

REFERENCE LITERATURE

DIRECTORIES

The Aeroplane Directory of British Aviation, Incorporating Who's Who in British Aviation. London, Temple Press, Ltd., 1950. 574 pp. 10*s.* 6*d.*

This is the fourth annual postwar edition of this indispensable directory, covering military and civil government services, research establishments, and other agencies, operating companies, consultants, periodicals, airports, institutions, societies, clubs, and the aircraft industry. The British Empire is covered. The biographical section includes about 1,600 living persons. The industry section in this edition has been considerably expanded.

The Aviation Week Airport Directory, 1950. New York, McGraw-Hill Book Company, Inc., 1950. 262 pp. $3.00 in the U.S.; $6.00 in other countries.

Airports are listed by states and their facilities described, including telephone numbers, hours, and names of managers. Military airports and inactive fields are included. A separate section is devoted to seaplane facilities, and related information on radio facilities, gasoline taxes, and offices of Government and private agencies of interest to airport users is included.

HANDBOOKS

Kent's Mechanical Engineers' Handbook. Power, J. Kenneth Salisbury, Editor. **Design and Production,** Colin Carmichael, Editor. 12th Ed. New York, John Wiley & Sons, Inc., 1950. 2 Vols. 1,560, 1,661 pp., diagrs. $8.50 per vol.

This is the first revision since 1936 of this standard work, originally published in 1895.

The Power volume has been almost completely rewritten by about 80 authorities, with emphasis on new developments in such fields as atomic power, combustion gas turbines, supersonic aerodynamics, jet propulsion, aircraft piston engines, heat pumps, panel heating, axial-flow compressors, instrumentation, and Diesel and electric locomotives. The broad purpose of this volume is to cover the entire field of heat-power engineering and transportation and the more important aspects of fluid flow.

The Design and Production volume is directed primarily toward engineers who design and manufacture machinery. Its 28 sections, written by 92 specialists, cover selection of materials, design principles, design and selection of machine components, and production processes and plant equipment. Both volumes contain sections of mathematical tables and numerous bibliographies, and they have been considerably expanded.

SCIENCES, GENERAL

MATHEMATICS

Contributions to the Theory of Nonlinear Oscillations. Edited by S. Lefschetz. (Annals of Mathematics Studies No. 20.) Princeton, N.J., Princeton University Press, 1950. 350 pp. $4.00.

Contents: On Systems of Ordinary Differential Equations, S. P. Diliberto; Oscillation of a Third Order Nonlinear Autonomous System, L. L. Rauch; Nonlinear Difference-Differential Equations, F. H. Brownell; Forced Oscillations in Nonlinear Systems, M. L. Cartwright; Singular

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Perturbations of a Van der Pol Equation, J. G. Wendel; The Existence of Forced Periodic Solutions of Second Order Differential Equations near Certain Equilibrium Points of the Unforced Equation, C. E. Langenhop and A. B. Farnell; and The Construction of Periodic Solutions of Singular Perturbation Problems, Wolfgang Wasow.

The Anatomy of Mathematics. R. B. Kershner and L. R. Wilcox. New York, Ronald Press Company, 1950. 416 pp. $6.00.

The authors provide a treatise on the axiomatic method and a reference source for workers in those sciences that are increasingly using the results and techniques of abstract mathematics. The axiomatic method is presented primarily by example in order to enable the reader to achieve appreciation of the subject by close contact. Dr. Kershner is associated with the Applied Physics Laboratory of The Johns Hopkins University, and Professor Wilcox is with the Illinois Institute of Technology.

PHYSICS

The Acceleration of Particles to High Energies. London, Institute of Physics, 1950. 58 pp., illus. 10*s*. 6*d*.

The papers presented here were read at a session of the Electronics Group of the Institute of Physics in May, 1949. They are as follows: The Cyclotron, J. Rotblat; Betatrons and Synchrotrons, F. K. Goward; Electrostatic Generators, E. S. Shire; Linear Accelerators, E. S. Shire. There is a separate section of discussions on the papers. Footnote references are included throughout, and indexes of subjects and of authors are provided.

Electron Diffraction. R. Beeching. 2nd Ed. London, Methuen & Company, Ltd.; New York, John Wiley & Sons, Inc., 1946. 107 pp., diagrs. $1.25.

Originally published in 1936, this monograph is reprinted largely without change. Bibliographies are given at the ends of chapters, and author and subject indexes are provided.

History of Physics. Max von Laue. Translated by Ralph Oesper. New York, Academic Press, Inc., 1950. 150 pp. $2.30.

This valuable history was first drafted in Germany in 1943. Beginning with the measurement of time, mechanics, gravitation and action at a distance, and optics, the reader is taken through electricity and magnetism, theory of heat, the law of conservation of energy, thermodynamics, atomistics, and nuclear physics. The three final chapters deal with the physics of crystals, head radiation, and quantum physics. The historical treatment of discoveries in each of these fields is brought up to 1940, and their interrelationships are partly brought out by the name and subject indexes.

THERMODYNAMICS

Applied Thermodynamics Problems for Engineers. W. J. Peck and A. J. Richmond. London, Edward Arnold & Company; New York, Longmans, Green & Company, Inc., 1950. 344 pp., diagrs. 21*s*. $4.00.

The purpose of the authors is to present a wide selection of worked examples, with explanations enabling the student to follow the solutions logically. The book is intended to supplement existing textbooks and to serve as an aid to studies for final engineering degree, professional institution, and scholarship examinations. Aside from the fundamental chapters, the topics treated include air compressors, internal-combustion engines, turbines, combustion, steam and its applications, the Rankine cycle, and heat transfer.

Les Diagrammes Thermodynamiques. G. Goudet and A. Proust. Paris 6, Dunod, 1950. 2 Vols. 414 pp., 23 folded charts. 4,850 Fr. per set.

The first 96 pages of this excellent work are devoted to the theory of thermodynamics, and nearly half of this part deals with equations and with formulas derived from them, on the flow of elastic fluids. The next twelve chapters, 241 pages, are concerned first with diagrams of entropy, then with other diagrams used in practice and discuss the conditions of their use and their limitations. In the final section are given examples of the use of diagrams in problems of nozzles and diffusers, and the discussion includes Fanno curves and shock waves, the representation of cycles, and applications to turbines and compressors. The authors are engineers with La Société Oerlikon and Les Houilières Nationales, respectively.

Convection de la Chaleur en Régime Permanent. R. Legendre. Paris 6, Dunod, 1949. 118 pp., diagrs.

Introductory chapters cover the coefficients of heat transfer by forced convection and heat exchangers. The discussion then proceeds into general laws of similitude, preparing the way for the study of simple phenomena as proofs. The role of turbulence is taken up in the same way, though lack of sufficient actual knowledge of turbulence makes the proofs short. The laws of similitude are then generalized for empirical results, including various cases of turbulent flow in tubes, laminar flow in circular tubes, and cases of multiple tubes. The book closes with an analysis of the practical problem of laminar flow over a blade.

Special I.A.S. Publications

Sherman M. Fairchild Publication Fund Papers

No.		Member Price	Nonmember Price
FF-2	A Study of the Flow, Pressures, and Loads Pertaining to Prismatic Vee-Planing Surfaces—Experimental Towing Tank, Stevens Institute of Technology.	$1.20	$1.60
FF-1	Ice Protection for Turbojet Transport Airplane (In Three Parts)—P. T. Hacker, R. G. Dorsch, T. F. Gelder, J. P. Lewis, H. C. Chandler, Jr., and S. L. Koutz.	$0.75	$1.25
286	Linearized Treatment of Supersonic Flow Through Axi-Symmetric Ducts with Prescribed Wall Contours—Charles E. Mack, Jr., and Ignace I. Kolodner.	$0.75	$1.25
244	Wetted Area and Center of Pressure of Planing Surfaces—Experimental Towing Tank, Stevens Institute of Technology.	$0.75	$1.00
229	Wave Profile of a Vee-Planing Surface, Including Test Data on a 300 Deadrise Surface—Experimental Towing Tank, Stevens Institute of Technology.	$1.20	$1.60
170	Wave Contours in the Wake of a 10° Deadrise Planing Surface—Experimental Towing Tank, Stevens Institute of Technology.	$1.20	$1.60
169	The Discontinuous Fluid Flow Past an Immersed Wedge—Experimental Towing Tank, Stevens Institute of Technology.	$0.75	$1.00
168	Wave Contours in the Wake of a 200 Deadrise Planing Surface—Experimental Towing Tank, Stevens Institute of Technology.	$1.20	$1.60
167	On the Pressure Distribution for a Wedge Penetrating a Fluid Surface—Experimental Towing Tank, Stevens Institute of Technology.	$0.75	$1.00
166	An Analysis of the Fluid Flow in the Spray Root and Wake Regions of Flat Planing Surfaces—Experimental Towing Tank, Stevens Institute of Technology.	$1.20	$1.60
165	Theory and Practice of Sandwich Construction in Aircraft (A Symposium).	$1.85	$2.50
164	Applications of the Theory of Free Molecule Flow to Aeronautics—Holt Ashley.	$1.15	$1.50
106	Measurement of Ambient Air Temperature in Flight—W. Lavern Howland.	$0.35	$0.50
105	An Evaluation of the Importance of Fatigue Phenomena in Aircraft—C. R. Strang, L. R. Jackson, L. F. McBrearty, R. V. Rhode, and R. L. Schleicher.	$0.80	$1.10
104	Tensor Analysis of Aircraft Structural Vibration—Charles E. Mack, Jr.	$1.85	$2.50
102	Electrical Resistance Strain Gages Applied to Wind-Tunnel Balances—Elmer C. Lundquist.	$0.60	$0.80
101	Introduction to Shock Wave Theory—J. G. Coffin.	$2.65	$3.50
100	Blade Pitching Moments of a Two Bladed Rotor—R. W. Allen	$0.75	$1.00
126	External Sound Levels of Aircraft—R. L. Field, T. M. Edwards, Pell Kangas, and G. L. Pigman	$0.75	$1.00

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automatic resetting, positive protection
The new *Kidde* Aircraft Fire Detector, now in the approval stage, is made from a continuous fire sensing element which has no moving parts. Made to fit easily around nacelles and other danger spots, it will repeat fire signals without resetting—can be set to give warning when predetermined temperatures are exceeded. Fire-resistant, it is unaffected by fungus, moisture, salt or other agents which might cause malfunction.
When the element is exposed to flame, or predetermined temperature, a signal light, which can be hooked up with a howler, warns the pilot. The warning signals stay on as long as fire exists—go out when the fire is out. They will repeat the signal, without manual resetting, if fire should strike again.
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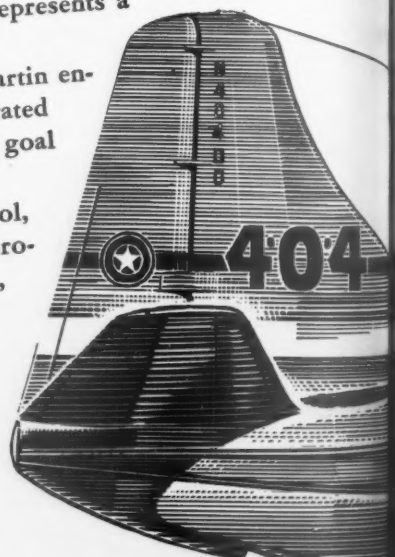

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Corporate Member News

(*Continued from page 11*)

• Dividend . . . **Curtiss-Wright Corporation** declared a dividend of 25 cents on its common stock, payable June 19. The second quarterly installment of 50 cents a share on the Class A stock was paid June 9.

• First Flight . . . The XA2D Skyshark, a Navy attack bomber designed by **Douglas Aircraft Company, Inc.,** has completed its first test flight. It is powered by the twin-turboprop T-40, a product of Allison Division of General Motors Corporation, which drives two counterrotating propellers, designed by General Motors' Aeroproducts Division . . . Accelerated service testing of the Douglas C-124A Globemaster II began last May following delivery of the first production model to the Air Materiel Command . . . For the fiscal year ending November 30, 1949, Douglas reported net earnings of $5,516,700 or $9.19 per share. The backlog was $275,499,000.

• Anniversary . . . The year, 1950, marks the 25th anniversary of the **Edo Corporation.**

• Test Runway . . . **Fairchild Aircraft Division,** Fairchild Engine and Airplane Corporation, has developed a "portable testing runway" that duplicates landing speeds up to 160 m.p.h., including the resulting drag and shock conditions.

• Dividend . . . **Fairchild Engine and Airplane Corporation** declared a dividend of 20 cents per share, payable last June 28 to stockholders of record on June 17.

• Air Flow Photographed . . . An instrument designed to facilitate observation and photography of airflow phenomena has been announced by **General Electric Company's** Special Products Division. The instrument, known as the "Schlieren Light Source," is a self-contained unit housing power supply, control circuits, lamps, and optical system. It furnishes continuous and high-intensity flash illumination.

• Portable Darkroom . . . A portable photographic darkroom and briefing tent, measuring 80 by 21 by 16 ft., has been developed by **The B. F. Goodrich Company.** The rubberized Fiberglas-Nylon room can be inflated in 6 min. and deflated in 25 min. The tent weighs 740 lbs. and may be packed in eight duffle bags.

• New Hull Planing Bottom . . . **Goodyear Aircraft Corporation,** a division of The Goodyear Tire & Rubber Company, has incorporated onto a standard Goodyear GA-2 three-place amphibian the N.A.C.A. planing-tail type of hull, for which improved water and flight characteristics are claimed. The hull has a deep-pointed step and a long afterbody.

• 40th Anniversary . . . The aviation department of the **Goodyear Tire & Rubber Company** is celebrating its 40th year.

• Canada Buys TBF . . . The Canadian Government has ordered an undisclosed number of TBF Avenger torpedo bombers, manufactured by **Grumman Aircraft Engineering Corporation,** for use as an anti-submarine weapon.

• Dual-Rotation Prop. . . **Hamilton Standard Division,** United Aircraft Corporation, has developed an eight-bladed dual-rotation propeller for use on high-powered gas-turbine engines developing in excess of 5,000 hp. It consists of two four-bladed propellers, placed one in front of the other on a dual shaft . . . Hamilton Standard has been awarded three Naval contracts for propeller assemblies, totaling $2,668,198.

• Guncharger . . . Type B-1 Automatic Guncharger, developed by **Walter Kidde & Company, Inc.,** has been approved by the Air Force for use on 50-cal. machine guns carried by military aircraft of all types. The charger, which is driven by compressed air, can be operated by remote electrical control, by local manual control, or automatically.

• 400-Cycle Motors . . . **Lear, Inc.,** has supplemented its current production of a.c., d.c., and high-frequency motors with four new frame sizes of 400-cycle motors having ratings up to 2-hp. output at speeds to 10,900 r.p.m. The new models have integrally constructed a.c. brakes that provide instant stopping of rotor and load and are available in intermittent and continuous duty versions.

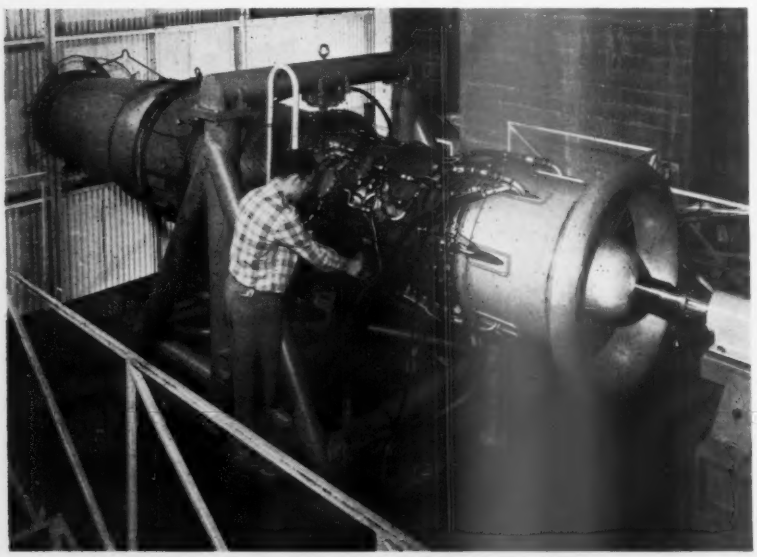
• Tail Modification . . . After completing a series of test flights at Edwards Air Force Base, Calif., the F-97 fighter was returned to the **Lockheed Aircraft Corporation** plant for tail modification. It is powered by a Pratt & Whitney J-48 engine equipped with an afterburner . . . Lockheed's profit for the year ending December 31, 1949, amounted to $5,491,000 after taxes. Dividends of $2.00 per share were paid, and the year-end backlog was $229,746,000.

• Altitude Record . . . The Viking rocket produced by **The Glenn L. Martin Company** set a new record for single-stage American-built guided missiles last May when it reached an altitude of 106.4 statute miles. It was fired in the mid-Pacific from the Navy experimental guided-missile ship, U.S.S. "Norton Sound." The Viking measures nearly 50 ft. in length and 32 in. in diameter; it is propelled by a liquid-oxygen and alcohol rocket motor, built by Reaction Motors, Inc. The rocket is expected to be used in cosmic-radiation research . . . A new hard coating for aluminum, designated as "MHC" finish, has been developed by the Martin company. This opens a way for industry to utilize more completely this lightweight metal.

• Noise Suppression . . . **McDonnell Aircraft Corporation** has begun an $80,000 noise-suppression and heat-dissipation program in connection with the testing of jet-engine installations.

• New Building . . . **Minneapolis-Honeywell Regulator Company** has begun construction of a new building in Minneapolis to house its aeronautical engineering department. The building, which will adjoin the company's aeronautical production plant, will be a two-story reinforced concrete and brick structure of 80,000 sq. ft., with footings for an additional story of 40,000 ft. Occupancy is expected November 1, 1950. The division's sales, service, and administration departments will also move into the new building.

• Acceptance Test . . . **North American Aviation, Inc.,** has announced that the RB-45C, latest version of the U.S.A.F. B-45



TURBODYNE ENGINE QUALIFIED FOR PRELIMINARY FLIGHT TESTS

With the completion of the 50-hour endurance proving program, the XT-37, developed by Turbodyne Corporation, a subsidiary of Northrop Aircraft, Inc., takes its place as one of the world's most powerful aircraft engines. During tests, the Turbodyne engine, designed for pusher, as well as tractor, installation, delivered more than 10,000 hp. and set a new record by sustaining a 7,500-hp. output over long intervals of time. The 8.25 to 1 reduction gear is a product of Western Gear Works; the six-bladed, constant-speed propellers were designed by Aeroproducts Division, General Motors Corporation; and the single-lever, automatic electronic control system was manufactured by Eclipse-Pioneer Division, Bendix Aviation Corporation.

Tornado bomber, has successfully completed its initial series of test flights and evaluation and acceptance tests for the Air Force. Powered by four General Electric J-47A jet engines, each with a static thrust of 5,200 lbs., the RB-45C is placed in the 550 m.p.h. class . . . North American has received a contract from the Air Materiel Command for the installation of air-to-air refueling equipment in the four-jet RB-45C . . . *Skyline* magazine, quarterly publication of North American, was selected for the "highest award" in the annual international industrial publications contest . . . Canada has purchased 100 North American F-86 operation jet fighters for use in the Canadian-United States air defense network.

• First Flight . . . The YRB-49A, a six-jet photoreconnaissance Air Force bomber produced by **Northrop Aircraft, Inc.,** has completed its first test flight. It is powered by Allison J-35 engines . . . As of January 31, 1950, Northrop's backlog was $54,000,000.

• Concrete Dock . . . **Northwest Airlines, Inc.,** is building a large concrete dock extending to the aircraft apron at Wold-Chamberlain Field in Minneapolis to facilitate handling air cargo. A conveyer belt will carry cargo from the end of the dock into the associated building.

• Naval Orders . . . **Pratt & Whitney Aircraft Division,** United Aircraft Corporation, has received contract awards from the U.S. Navy totaling $51,047,418 for aircraft engines . . . The first Consolidated Vultee T-29 navigational trainer has been delivered to Ellington Air Force Base, Tex. The T-29 is powered by Pratt & Whitney Double-Wasp engines.

• New Distributor . . . **The Parker Appliance Company** has appointed Van Dusen Aircraft Supplies, Inc., as its distributor for aircraft tube fittings, valves, and other products.

• Employees Buy Stock . . . Employees of **Phillips Petroleum Company** have inaugurated a stock-purchase plan to make every worker a part-owner of the company. The stock is purchased on the open market and is not new stock issued by the company.

• First Flight . . . Less than 6 months since the engineering was begun, the XF-96A Thunderjet completed its initial flight successfully. This swept-wing version of the F-84 Thunderjet has a performance exceeding that of its predecessor. It is a product of **Republic Aviation Corporation.**

• Compressor Blade Polisher . . . A rotary polisher for jet-engine compressor blades has been developed by **A. V. Roe Canada Limited.** This machine, mounting 20 blades, can give, within 15 min., a surface smoothness of the order of 3 microinch without materially affecting the contour of the blades as forged or machined . . . To prevent hydrogen peroxide from freezing when being used as a fuel for starting a motor, A. V. Roe has developed a system in which a small quantity of the hydrogen peroxide is used as a source of heat.

• Helicopter Orders . . . The U.S. Navy accepted delivery on the first H-19 helicopter, manufactured by **Sikorsky Aircraft Division,** United Aircraft Corporation, and has ordered ten Sikorsky HO4S helicopters, powered by Pratt & Whitney 600-hp. Wasp engines.

WRIGHT COMPOUND ENGINE POWERS LOCKHEED NEPTUNE

The first production-type aircraft to be fitted with compound engines has completed its first flight. The plane is the P2V-4 Neptune, manufactured by Lockheed Aircraft Corporation; the power plants are the new Turbo-Cyclone 18 compound engines, made by Wright Aeronautical Corporation Division of Curtiss-Wright Corporation. Cylinder exhaust gases that are piped directly to three small turbines (encircled) allow about 20 per cent more power to be generated without additional fuel. This added power is fed to the crankshaft and thence to the propeller by a series of gears and fluid couplings. By recovering this usually wasted energy in the exhaust, the compound engine produces 3,250 hp., 550 hp. more than the basic engine without the turbines but with no increase in fuel consumption. This fuel saving may be translated into an increase in either range or speed, depending on the pay-load requirements.

• Engine Cowling Latch . . . The Simmonds High-Strength Cowling Latch, now being manufactured by **Simmonds Aerocessories, Inc.,** weighs from 6 to 8 oz. and is designed to carry an ultimate load of approximately 7,000 lbs. in tension and 9,000 lbs. in shear . . . Simmonds has introduced an electronic fuel gage. Among the devices that it can operate are high- and low-level warning lights, fuel transfer pumps, tandem indicators, counter-type indicators, and a Simmonds Totalizer Unit.

• Zero Readers . . . **Sperry Gyroscope Company Division,** The Sperry Corporation, has received a contract from North American Aviation, Inc., for Zero-Reader flight instruments to be installed in F-95A fighters. This instrument enables pilots to make approaches at lower weather minimums on beam-landing systems such as I.L.S. Deliveries are scheduled to begin this summer . . . Sperry electronic engine analyzers are being installed in the Boeing B-50D bombers and C-97A transports. The analyzer locates detonation the instant it occurs and aids maintenance procedures by identifying a malfunctioning engine component.

• Pressurization Units . . . **Stratos Corporation,** a subsidiary of Fairchild Engine and Airplane Corporation, has announced the sale of cabin-pressurization units to Pan American World Airways System. The order for the Model S60 units totals approximately a quarter of a million dollars, with delivery to begin this summer.

• Corporate Name . . . The corporate name has been changed from Transcontinental and Western Air, Inc., to **Trans World Airlines, Inc.** The latter name has been used as a trade style since 1946.

• Publications Honored . . . Three of **United Aircraft Corporation's** house organs have won awards in the international industrial publications contest. *The Beehive,* a quarterly, won the highest award for the third consecutive year. Honorable awards were won by the annual *Pictorial Report* and *The Power Plant,* Pratt & Whitney Aircraft Division's monthly newspaper . . . The U.S. Navy has awarded contracts totaling $53,715,616 to United Aircraft Corporation for engines and propeller assemblies.

• J-34 Certified . . . The J-34, manufactured by **Westinghouse Electric Corporation,** has been certified by the C.A.A. for commercial use. An axial-flow engine having eleven stages and driving a two-stage turbine, the J-34 has a military rating of 3,000 lbs. static thrust and weighs 1,200 lbs.

• Dividend . . . A dividend of $1.25 a share on the common stock was payable on June 15 by **Wright Aeronautical Corporation Division** of Curtiss-Wright Corporation.

1927

Alcoa Aluminum flew with Lindy to LeBourget

Millions wondered, "Will he make it?" Millions rejoiced when he did—the first successful air hop from New York to Paris, a daring feat that helped make today's transocean flights a daily routine. One reason Lindbergh made it was that he flew a plane vastly superior to those a few years older. His sturdy Ryan monoplane utilized Alcoa Aluminum in its fuel tanks, nose cowl, trailing edge of wing and wing strut fairings. In the pistons, cylinder heads and crankcase of its famous Wright Whirlwind engine.

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I.A.S. Sections

Boston Section

R. Douglas Smith, *Secretary*

Activities for the year were closed with the Fourth Annual Spring Dinner Meeting on May 24. Following the Dinner at the Thomson Club, Nahant, Mass., the speaker, George W. Brady, F.I.A.S., Director of Engineering, Propeller Division, Curtiss-Wright Corporation, was introduced by Robert R. Dexter, Secretary, I.A.S.

▸ **Modern Propellers**—Mr. Brady presented an illustrated lecture on "The Future of the Propeller in Aircraft." He covered present-day aircraft, American and British, and proceeded to discuss the physical characteristics of propellers now under development. Curves showing typical performances of these propellers indicate that the current trend is to better efficiencies at much higher airplane speeds. Emphasis was placed on the fact that good efficiencies are obtained for thin-profile propellers at speeds of 500 m.p.h. The characteristics of the turbine engine and propeller plant for airplanes where high subsonic speed, long range, and maximum efficiency must be obtained were indicated. An analysis of a long-range transport with various types of power plants was given.

During the discussion that followed, advocates of the compound engine were heard, as well as those who felt that perhaps the component efficiencies of the propulsion systems were not all typical of those obtainable today.

Chairman W. O. Meckley closed the meeting. Following this, members became acquainted with Mr. Dexter and with Thomas J. Meskel, Manager, Member Services, I.A.S., who accompanied Mr. Brady to Boston.

Cleveland-Akron Section

William A. Fleming, *Secretary*

The April 25 meeting, attended by 50 persons, was held in Polsky's Tea Room, Akron. Dr. Willard P. Berggren, Chief Engineer, Rocket Research Laboratory, Research Foundation, The Ohio State University, spoke on "Trends in Rocket Propulsion Research." Largely confined to generalities by the restricted classification of his subject, Dr. Berggren outlined the various steps to be taken in rocket research and pointed out the research steps that should precede development work on rockets. He indicated that, because of the demand for immediate application, development of workable rocket motors has actually preceded the basic research.

Two films were shown. The first explained the operation of a jet engine; the second showed a number of current fiighter and bomber aircraft in flight.

Chicago Section

Alfred F. Stott, *Secretary*

On May 26, 81 members and guests assembled at the U.S. Naval Air Station, Glenview, Ill. During a tour of the facilities, the group inspected the aircraft, instructional equipment, and hangars and witnessed a flight exhibition staged by four F-38's. Dinner was then served at the Commissioned Officers' Club, after which Lt. Comdr. Richard Schram, in charge of the programming and arrangements, gave a brief description of Naval flight operations. A film covering these operations was shown.

During a business meeting at the dinner, Chairman Harold V. Hawkins called for the election of officers, with the following results: Chairman, Kenneth L. Burroughs; Vice-Chairman, Robert H. Wendt; Secretary, Alfred F. Stott; and Treasurer, C. N. Lusty.

Detroit Section

Joseph Rutkowski, *Secretary*

The dinner meeting of April 28 was held at Wayne University Student Center and was "emceed" by Richard R. Crandall, a student at Wayne. The "Third Annual Student Technical Paper Award," sponsored by the Section, was presented to Thomas E. Campbell. (See page 7 of this issue.)

▸ **Transonic Research** — Guest speaker of the meeting was Eugene C. Draley, Aeronautical Research Scientist, N.A.C.A., Langley Air Force Base, Va., whose topic was "N.A.C.A. Transonic Research Techniques" In his talk, Mr. Draley described the development by the N.A.C.A. of various transonic research techniques, which include the wind tunnel, drop body, rocket-propelled missile, research airplane, and wing-flow and bump methods. With reference to model-support systems, he showed that new types are required, since extremely small models must be used in the conventional wind tunnels for the close approach to the speed of sound. Advantages may also be obtained by employing other special types of wind-tunnel apparatus. In describing the instrumentation required for flight techniques, Mr. Draley emphasized that they have depended to a large extent on the development of special radar and telemetering equipment for the procurement of experimental data. The use of all of these research techniques by the N.A.C.A. in various combinations has led to an extensive improvement in the rate of procurement of transonic research information necessary for the design of aircraft to fly through the speed of sound.

Results of an election were announced, and the following were voted into office: Chairman, Henry H. Kerr; Vice-Chairman, Frederick A. Hiersch; Secretary, George Melby; and Treasurer, Gordon C. Page.

Hagerstown Section

Logan T. Waterman, *Secretary*

The meeting of April 4 was held at the Loyal Order of Moose Hall and was attended by 30 people. Walter Johnson, Department of Applied Science, International Business Machines, spoke on the "Development of Automatic Sequence Calculators for the Solution of Technical Problems." Mr. Johnson outlined the development of the calculator, as well as its application to aeronautical engineering problems. Chairman D. W. Weller presided.

The 75 persons attending the May 2 meeting at the Loyal Order of Moose Hall heard Rear Adm. L. B. Richardson, U.S.N. (ret.), Director of Research and Development, Fairchild Engine and Airplane Corporation, talk on "Industry's Role in Translating Research into Aircraft Development." Admiral Richardson is an I.A.S. Fellow and a member of the I.A.S. Council. Mr. Kellhofer, Manager, Sales and Service, Fairchild Aircraft Division of Fairchild Engine and Airplane Corporation, gave a report on "Operation Swarmer," the Army maneuvers conducted last spring in North Carolina. Chairman Weller presided.

Los Angeles Section

H. A. Storms, *Secretary*

A specialist meeting was held at the I.A.S. building on April 6, at which time Dr. E. R. Van Driest, M.I.A.S., Group Leader, Theoretical Aerodynamics, North American Aviation, Inc., presented a lecture on "The Boundary Layer in Compressible Flow." Approximately 70 members were in attendance.

▸ **Equation Development**—The talk was concerned mainly with the de-

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velopment of equations presented in North American's Aerophysics Laboratory Reports AL-958 and AL-997. Using slides to present the equations, Dr. Van Driest went through the derivations of the boundary-layer equations in detail, covering all assumptions involved and the importance of certain parameters to the accurate determination of skin temperatures. The discussion that followed was largely confined to the experimental verification of the calculated results. Dr. Van Driest covered some of the limitations of his theory during the discussion.

The April 20 meeting was called to order by Chairman Phillip A. Colman and was devoted to cold-weather operation of aircraft, with Capt. Frank W. Horn, Jr., U.S.A.F., Chief, Climatic Requirements Unit, as the speaker, assisted by Capt. James S. Humphrey, Jr., U.S.A.F., Chief, Equipment Unit, Climatic Projects Sections, as his assistant. The subject of Captain Horn's talk was "Research and Development for Aircraft Operation in Cold Weather."

▸ **Maintenance Problems**—Operational aircraft, according to a U.S.A.F. requirement, must be capable of operation in temperatures from 160° to −65°F., with a storage temperature as low as −85°F. However, complying with this mandate under cold-weather conditions encountered in the Arctic areas has raised many difficult problems. Among them are such things as: (1) the heavy cumbersome clothing that must be worn by maintenance crews; (2) the solidifying of certain reciprocating-engine lubricants at −65°F., necessitating a 35 per cent oil dilution at that temperature; (3) the contraction and expansion of aircraft structures and equipment throughout the entire temperature range; (4) the lower volatility of fuels at low temperatures, resulting in hard-to-start engines; (5) the aircraft icing, including that occurring before take-off; (6) the leakage of the hydraulic system at low temperatures; (7) the reduction at low temperatures of the film speed of photographic equipment; (8) the survival of personnel in the event of a crash landing or of bailing out.

▸ **Films**—Four motion pictures were shown: the climatic hangar at Eglin Air Force Base, Fla.; propeller deicing at Wright-Patterson Air Force Base, Dayton, Ohio; research on top of Mt. Washington; and operations at Ladd Air Force Base, Alaska, showing the cold-weather operation of the C-54, C-119 with track gear, F-84, B-45, and B-36. Approximately 150 members attended.

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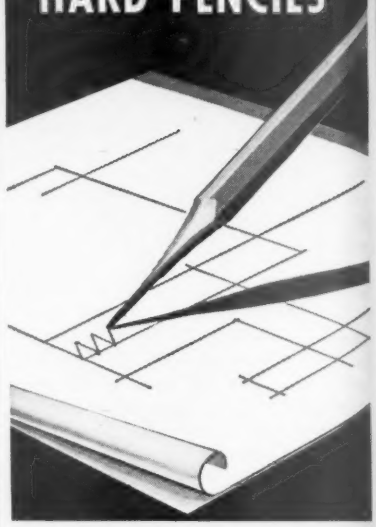

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Speakers of the evening at the April 6 meeting were Dr. H. Dunholter and Dr. H. Brennen, both of whom are affiliated with the Thermodynamics Group, Consolidated Vultee Aircraft Corporation. Their subject was the "Fundamentals of Atomic Energy," and their talk was accompanied by pictures of the test atomic explosions at Bikini. The meeting was held in the new building.

On May 4, Bruce Smith, Chief Engineer, Ryan Aeronautical Company, presented a talk on "Design Criteria Affecting Fighter Aircraft Configurations." Mr. Smith illustrated his talk with slides that showed the history of speed, thrust, and weight of fighter aircraft from World War I to the present time. Since the advent of the jet engine, the above three parameters have literally skyrocketed so that the design of single-seater fighters calls for entirely new criteria. He felt that possibly too steep a price was being paid for speed considering the inefficiency of engines and that the supersonic barrier was considerably overrated.

Student Branches

Academy of Aeronautics

A joint meeting of the I.A.S. Student Branches of the New York Metropolitan area was held on May 10. With the faculty and students of the Academy of Aeronautics acting as hosts, representatives from the Polytechnic Institute of Brooklyn, New York University, and Stewart Technical School participated.

After various student projects were examined, the guests heard Jack Cassamassa, Senior Instructor, Engineering Department of the Academy, present an illustrated lecture on the operation of a jet engine. Thomas Buckley, Chairman of the I.A.S. Student Branch at the Academy, spoke on the economic aspect of jet engines as compared with the reciprocating engines for regular commercial operation. The meeting concluded with an inspection of the laboratory facilities.

Cal-Aero Technical Institute

On April 18, George Bogert, Office of Regional Administrator, C.A.A., spoke on the C.A.A. and outlined its various functions, including the manner in which a plane is certified. This was accompanied by a film that showed a few phases of the ground-testing operations during certification. Chairman John U. Sweeney led the meeting, and 150 persons attended.

The meeting of May 18 was also attended by 150 persons. They heard Arthur L. Jocquel, Rocket Research Institute, California Institute of Technology, speak on "Interplanetary Rocket Travel." On the assumption that all difficulties in constructing space ships were overcome, Mr. Jocquel described the first few rocket trips to the moon. He concluded by saying that these events were not impossible and would happen soon. Chairman Sweeney presided.

California State Polytechnic College

On March 16, Vice-Chairman Andrew Acampora conducted the meeting at which papers were presented by three Student Members. H. H. Choate spoke on "Air Line Careers," Jack Graham on "Testing Spot Welds," and William C. Heath on "A Matrix Solution of a System of Simultaneous Equations." Two motion pictures were shown: *How an Airplane Flies*, a series of six films produced by the Shell Oil Company, Inc., dealing with lift, drag, thrust, and other factors of aerodynamics; and *The Science of Flight*, distributed by Lockheed Aircraft Corporation, depicting the various phases of testing the Constellation.

Student Members R. K. Richardson, H. R. Kramp, and R. P. Bethel presented talks at the March 28 meeting. Mr. Richardson spoke on "Tempering Theory with Practice," Mr. Kramp on "Nonskid Devices for Aircraft," and Mr. Bethel on "Airport Profits." A film, *Jet Propulsion*, produced by General Electric Company, was shown. Chairman William C. Heath officiated.

On April 13, the first annual joint meeting with the S.A.E. Student Branch was held, and papers were given by both I.A.S. and S.A.E. student members. L. C. Quigg and A.C. Lee, I.A.S. Student Members, spoke on "Metal Spar Splices" and "Advantages of Aircraft Cabin Pressurizing." S.A.E. Student Members Frank Pilling and Al Morrison presented papers on "Alcohol Injection" and "Inspection of Rotary Cutters." Two motion pictures from Republic Aviation Corporation, *A Thunderbolt Is Made* and *Ground Handling of the P-47*, were shown. I.A.S. Chairman Heath and S.A.E. Branch President Albert Gornbine presided.

I.A.S. Student Member Thomas Watson presented a paper at the April 27 meeting entitled "How High Is Your Ladder?" outlining the problems confronting a young graduate engineer. Two films from North American Aviation, Inc., were shown: *The Nativ*, depicting the story of a test rocket in actual firings; and *Latest Showing of North American Aviation Aircraft*, which demonstrated flight tests of various jet aircraft. Chairman Heath presided; 35 members and five guests attended.

Two members of the faculty spoke at the May 11 meeting led by Chairman Heath. James Smith, of the English Department, gave a talk on art and eye appeal in the design of aircraft. Mr. Bowden, of the college's Electronics Department, discussed the design, development, and use of the strain gage. The following officers were elected: Chairman, Milo V. Price; Vice-Chairman, C. Sherburne; Recording Secretary, David Fuller; Corresponding Secretary, Charles A. Johnson; and Treasurer, George Bergst. Forty-six members and three guests attended.

At the May 20 dinner meeting, Lt. Comdr. George R. Fraser, U.S.N., Assistant Director, Range Instrumentation Department, U.S. Naval Air Missile Test Center, Point Mugu, Calif., spoke on "The Guided Missile as a Weapon." Lecture and scholarship awards were presented to R. K. Richardson and Nordae Rhodes. Vice-Chairman Andrew Acampora conducted the meeting; 40 members and 32 guests were in attendance.

Case Institute of Technology

The speaker at the April 5 meeting was Cook Cleland who spoke on "How to Make a Corsair Win the Thompson Trophy." The meeting was conducted by Chairman Robert W. Carr.

On April 26, R. E. Cummings, Assistant Manager and Chief Engineer, Jet Division, Thompson Aircraft Products Company, Thompson Products, Inc., gave a talk on "Problems in the Fabrication of Turbine Blades and Buckets." Slides were also shown. Chairman Carr presided.

The Catholic University of America

The following officers were elected at the May 10 meeting: Chairman, Jack Carney; Secretary, Edward Warner; and Treasurer, John Filicke. Mr. Samoyoa, of the class of 1928, spoke on "Air Transportation and Medicine." Two films, *Utility Unlimited* and *The Phantom*, were shown.

Chairman Woodrow Seamore presided.

Clarkson College of Technology

The following officers were elected at the May 2 meeting: Chairman, Robert Waters; Vice-Chairman, Louis Manno; Treasurer, Willis Rice; and Secretary, Harry Kent. Motion pictures shown included *Birth of the B-29*, an Army Combat film, and *Detonation, Preignition, and Knock in a Spark-Ignition Engine*, an N.A.C.A. film. Chairman Stephen A. Murtaugh presided.

University of Colorado

The speaker at the April 12 meeting was R. L. McBrien, Technical Development Division, United Air Lines, Inc., whose topic was "The Application of Jet Engines to Commercial Aircraft." Mr. McBrien commented on the conclusions found by a group of U.A.L. personnel who last February toured various foreign countries to investigate their aircraft industries. The talk was illustrated. Chairman Robert Fischer conducted the meeting.

On April 27, Col. Benjamin Mesick, U.S.A. Ordnance, spoke on "Guided Missiles and Their Application to Military Use." A film, *Armed Forces Screen Review*, was shown.

Cornell University

On April 11, Harry I. Ashkenas, T.M.I.A.S., Research Associate, Graduate School of Aeronautical Engineering, Cornell University, gave an illustrated talk on "Interferometry and Its Applications in Aeronautical Engineering."

University of Florida

A Ford Motor Company film, *Gliding Wings*, shown on May 2, was concerned with the manufacture of the CG4A glider. Chairman Edward Carrington Allison presided.

Georgia Institute of Technology

The I.A.S. Student Branch placed an original exhibit in the Hall of Engineering during Georgia Tech's Engineers' Week, April 24–31. This annual spring display was established for the purpose of acquainting the public with various phases of engineering and with the work done by the schools of engineering.

In order to demonstrate the principles of aerodynamics and the testing equipment used in wind tunnels, the I.A.S. Student Branch exhibit consisted of models of (1) a Curtiss Seahawk complete with floats and motor; (2) a smoke tunnel to illustrate two-dimensional flow over various ships; and (3) a spin tunnel to show the comparative drags of the older and newer types of aircraft streamlining. Blueprints and accompanying small-scale models of airplanes designed by senior students were also presented. Student Members served as guides for visitors touring the buildings.

On May 12, H. W. S. LaVier, M.I.A.S., Research Professor at Georgia Tech, presented a talk on "Georgia Tech's Supersonic Wind Tunnel and Water Table." Chairman Seymour Salmirs presided; 40 persons attended.

University of Illinois

Chairman Norman Gowin presided over the April 5 meeting at which two guest speakers were heard. G. A. Mosely, Instructor, Institute of Aviation, discussed the design of aircraft from the standpoint of maintenance. J. M. Stonecipher, Chief Flight Instructor, Institute of Aviation, and Assistant Manager, University of Illinois Airport, spoke on aircraft design from the pilots' angle.

On May 17, three papers were presented in competition for an I.A.S. Lecture Award. They were "Guided Missiles," by Allen Benson; "Transcontinental Rocket Air Power and Its Problems," by Donald Brown; and "Methods of Thrust Augmentation for Turbo Jets," by Kennith Benson. The award was won by Kennith Benson. Chairman Gowin presided.

The following officers were elected for the ensuing year: Chairman, Harvey Wallskog; Vice-Chairman, Loren Anderson; Secretary-Treasurer, Robert Johnson; and Engineering Council Representative, Corliss Laisure.

Illinois Institute of Technology

On March 28, a joint meeting of the Student Branches of the Chicago area was held. Members from the Aeronautical University, Notre Dame University, and Illinois Institute of Technology were in attendance.

The meeting was opened by Dr. Harold V. Hawkins, A.F.I.A.S., Professor, Civil Engineering, Illinois Tech, who spoke on "Trends in Aeronautical Engineering Education in Colleges and Universities." He discussed the emphasis placed on aeronautical education by colleges and universities throughout the United States.

Following a dinner with the Chicago Section of the I.A.S., the Student Members were their guests at a lecture given by Raymond Kelley, Chief Engineer, American Airlines System. In his talk on "Jet Transport Development," Mr. Kelley commented to the Student Members that the aeronautical field provided plenty of opportunity because of its comparative youth and progressive strides.

Indiana Technical College

Chairman John Mangan opened the April 12 meeting at which the film, *Faster Than Sound*, was shown. Twenty-four members attended.

On April 19, the following films were presented: *History of Variable-Pitch Propellers and the Aeroprop* and *Flying the P-47*. Chairman Mangan presided; 29 members attended.

University of Kansas

The following officers were elected at the May 16 meeting: Chairman, Verle V. VanCamp; Vice-Chairman, Richard L. Burnet; and Secretary-Treasurer, William C. Hand, Jr. Giles K. Smith, Student Member, presented a winning paper on "The Upper Atmosphere." Chairman John C. Adams presided; 35 persons attended.

Louisiana State University

Frank T. Carroll, Jr., M.I.A.S., Instructor, Mechanical Engineering, L.S.U., spoke at the March 23 meeting on the organization and benefits of the I.A.S. Chairman Joseph J. Cornish presided.

On May 4, the following officers were elected: Chairman, Robert P. Dawson; Vice-Chairman, Perry Stern; and Secretary-Treasurer, Theodore J. Gordon. Outgoing Chairman Cornish led the meeting.

Massachusetts Institute of Technology

Col. Crocker Snow, Director, Massachusetts Aeronautics Commission, gave a speech at the April 18 meeting on the topic "Airports for Jetliners." Chairman Henry R. Jax presided.

North Carolina State College

At the meeting of the May 23, the following officers took charge of their respective offices: Chairman, Reese Folb; Vice-Chairman, Harvey Neil Kelly; Secretary, Richard B. Kemper; Treasurer, John W. Kiker; and Publicity Chairman, Jack E. McCormick.

Northrop Aeronautical Institute

A joint meeting of the I.A.S. and S.A.E. Student Branches was held on April 6. Guest speaker Gene May, Test Pilot, Douglas Aircraft Company, Inc., devoted much of his talk to

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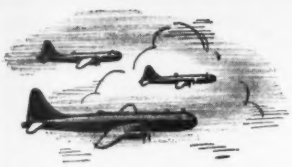

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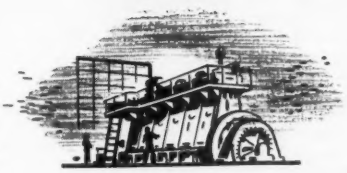

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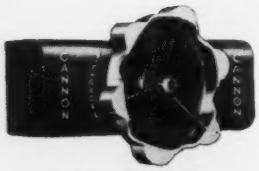

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the flight testing of the Skyrocket and of the Skystreak, which he piloted on its maiden flight.

Guest speaker at the May 31 meeting was Irvin Culver, M.I.A.S., Design Specialist, Lockheed Aircraft Corporation, who spoke on the problems of aircraft stability and control. Mr. Culver stated that, although both control and stability are essential in aircraft, control cannot be sacrificed in any respect to favor stability. The problem becomes more difficult and more important as the speeds of newer designs become greater, he declared.

University of Oklahoma

Winners of the annual awards for the outstanding student and lecture were won by Curtiss L. Walker for his outstanding ability as a student and by Francis M. Ford for his lecture on the "Caster Landing Gear." The following officers were elected: Chairman, Herold G. Coles; Vice-Chairman, John James; and Secretary-Treasurer, Jack D. Whitfield. Lieutenant Colonel Parkhurst, U.S.A.F.R., spoke on "The Relation of the Aeronautical Engineer to the Air Force." Outgoing Chairman Robert L. Dickinson presided.

Oregon State College

Stanley H. Lowy, M.I.A.S., Instructor, Aeronautical Engineering, Oregon State College, spoke at the May 3 meeting on "Modern Propulsion Systems." Chairman Elliott R. Buxton led the meeting, which was attended by 21 persons.

At a special meeting on May 9, the following officers were elected: Chairman, Richard L. Sears; Business Secretary, Albert A. Van Duine; Corresponding Secretary, George B. Webb; and Treasurer, Russell A. Wilmot. Chairman Buxton presided; 36 persons attended.

Parks College of Aeronautical Technology

At the dinner meeting of May 25, the speaker was Jack T. Wills, Sales Engineer, Allison Division, General Motors Corporation. He outlined the history of the Allison Division and noted many projects in which it has engaged since 1917. Mr. Wills' lecture was followed by a film entitled *Allison Jet Engines.* Chairman Wallace E. Carr presided; 51 persons attended. A presentation of the annual I.A.S. award to the outstanding engineering student of the college was made by Mr. Wills to Grant Parker.

On June 1, Chairman Carr led the meeting at which three films were

shown: *Martin 202*, from The Glenn L. Martin Company; *The Nativ* from North American Aviation, Inc.; and *Latest Aircraft*, from North American. Eighty persons were in attendance.

The Pennsylvania State College

Jerome Steffens, T.M.I.A.S., Instructor, Aeronautical Engineering, The Pennsylvania State College, spoke on "Rotary-Wing Aircraft." He gave some of his experiences in this field, gained from his working in the engineering department of the Piasecki Aircraft Corporation, and outlined many problems confronting helicopter designers. Slides shown included various types of helicopters, as well as diagrams of power and control systems. Chairman William Hendershott presided at this April 26 meeting; 55 persons attended.

On May 10, the speaker was Dr. James M. Robertson, M.I.A.S., Research Engineer, Ordnance Research Laboratory, The Pennsylvania State College. In his speech on "The Garfield Thomas Water Tunnel," he explained the mechanics of the tunnel, which, he said, will be used primarily for experimenting with torpedo propellers. A tour through the water-tunnel building followed the lecture. Chairman Hendershott conducted the meeting, which was attended by 60 persons.

University of Southern California

A field trip was made on May 8 to North American Aviation, Inc. The guides conducted an extensive tour through the plant, showing the students everything within the limits of security. The subsonic wind tunnel, in which a model of a Sabre was actually undergoing tests, was the high point of the trip.

Spartan College of Aeronautical Engineering

An election of officers was held on April 4 with the following results: General Secretary, Milton Larsen; and Corresponding Secretary, W. Ross Richardson. Chairman Earl G. Blosser presided; 50 persons attended.

On April 18, Student Member Robert Rouse discussed the latest issues of the AERONAUTICAL ENGINEERING REVIEW and the JOURNAL OF AERONAUTICAL SCIENCES.

A field trip for the purpose of touring the Wichita plants of Boeing Airplane Company and the Beech Aircraft Corporation took place on May 5.

Erratum

In the Student Branch report of Rensselaer Polytechnic Institute, published on page 88 of the June issue of the *Aeronautical Engineering Review*, the position title and professional connection of Robert Rosenbaum were erroneously listed. Mr. Rosenbaum's correct title is: Chief, Dynamics Section, Airframe and Equipment Engineering Branch, C.A.A.

Stanford University

Student Members Kinge Okauchi and Wendell Garton presented papers at the April 19 meeting on "Rocket Trajectories" and "Radio Navigational Aids." Two films were shown: one in color from Westinghouse Electric Corporation on *Navy Banshee and Westinghouse Jet Engine;* the other an N.A.C.A. film on the Ames Aeronautical Laboratory, Moffett Field, Calif. Chairman John Traynor presided.

Syracuse University

Dr. Paul E. Hemke, A.F.I.A.S., Dean of Faculty and Head, Aeronautical Department, Rensselaer Polytechnic Institute, spoke on "My Experiences in Aviation" at the May 3 meeting. Chairman Edward A. Stannard presided.

On May 8, the following officers were elected: Chairman, George Schmanke; Vice-Chairman, Harold Stewart; Secretary, Charles Stoddard; Treasurer, Robert Conine; and Faculty Adviser, Prof. L. Parkinson.

University of Wichita

The second annual University of Wichita Engineering banquet was held at the Allis Hotel on March 14. The speaker of the evening was Edward R. Stapley, Professor of Civil Engineering and Acting Dean of Engineering, Division of Engineering, Oklahoma Agricultural and Mechanical College. In the talk on "Slide Rules Plus," Dean Stapley stressed the importance of the part that engineers should play in community life. Daniel Carl was Chairman at the banquet attended by 40 persons.

On April 4, Charles M. Seibel, President, Seibel Helicopter Company, Inc., discussed "The History of Seibel Helicopters" and showed a film on the same topic. Vice-Chairman Carl A. Fowler, Jr., presided.

Members Elected

The following applicants for membership or applicants for change of previous grades have been admitted since the publication of the list in the last issue of the REVIEW.

Elected to Associate Fellow Grade

Crocco, Luigi, Dr. in Engineering, R. H. Goddard Professor, Princeton and Rome Universities.

Transferred to Associate Fellow Grade

Mack, Charles E., Jr., Sc.D. in Engineering, Chief of Research, Grumman Aircraft Engineering Corp.

Elected to MEMBER Grade

Arkus-Duntov, Yura, Lic. es Sc., Vice-President, Automotive & Aircraft, Hydraulics, Inc.

Avellaneda, Juan B., Ing., Chief, Flight Test Dept., Instituto Aerotecnico (Argentina).

Denaci, Herbert G., B. of A.E., Sr. Aero-Mechanics Engineer, Fairchild Engine & Airplane Corp.

Dorsey, Elmer T., M.S., Col., U.S.M.C., Commanding Officer, Marine Corps Aviation Technical School (Quantico).

Fisher, Wesley J., Production Engineer, Maintenance Base, United Air Lines, Inc.

Gillis, Clarence L., B.S. in M.E., Aero. Research Scientist, Pilotless Aircraft Research Div., N.A.C.A., Langley Air Force Base.

Levchuk, George, A.E., Ship Liaison Engineer, Chase Aircraft Co., Inc.

Lundin, Bruce T., B.S., Aero. Research Scientist, Flight Propulsion Research, Lewis Flight Propulsion Lab., N.A.C.A.

Manganiello, Eugene J., E.E., Asst. Chief of Research, Lewis Flight Propulsion Lab., N.A.C.A.

Maynard, Julian D., B.S. in M.E., Aero. Research Scientist, N.A.C.A., Langley Air Force Base.

McFarland, Jesse G., Jr., Design Engineer, Douglas Aircraft Co., Inc. (Long Beach).

Ogness, Russell S., B.S. in Ae.E., Fuselage Stress Analyst, North American Aviation, Inc.

Sessions, Robert C., B.S. (E.E.), Aero. Research Scientist & Executive Officer, Research Lab., N.A.C.A. (Cleveland).

Transferred to MEMBER Grade

Alberti, Paul L. E., B.S. in Ae.E., Group Engineer in Charge of Wing Design, Chance Vought Aircraft Div., United Aircraft Corp.

Dickinson, John Lovewell, A.B., Chief Engineer, Aero. Engineering School, Cal-Aero Technical Institute.

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Glaser, Jack, Sr. Design Engineer, Guided Missiles Div., Fairchild Engine & Airplane Corp.

Hasert, Chester N., M.S. in Ae.E., Chief, Aeroballistics Section II, Naval Ordnance Lab. (White Oak).

Rathke, Charles William, B.S. in M.E., Structures Project Engineer, Grumman Aircraft Engineering Corp.

Elected to Associate Member Grade

Shank, Wayne C., Instructor & Jet Research Com. Chairman, Cal-Aero Technical Institute; Chief Engineer & Structural Designer, Baumann Aircraft Corp.

Elected to Technical Member Grade

Anderson, Alvin M., B.S. (E.E.), Flight Test Analyst, Douglas Aircraft Co., Inc. (Santa Monica).

Colm, Guido, Technical Asst., Dowty Equipment of Canada, Ltd.

Transferred to Technical Member Grade

Abichandani, Krishin, B. of E. (Elec. & Mech.), Graduate Research Fellow, University of Washington.

Adams, Elliot L., B.S.

Allardt, Clark E., B.S. in Ae.E., Draftsman "A," Consolidated Vultee Aircraft Corp. (San Diego).

Alter, Kenneth R., B. of Ae.E., Student, University of Detroit.

Arnold, M. L., B.S. in M.E. (Aero.), Draftsman, Cessna Aircraft Co.

Aycock, W. C., Draftsman, Redstone Div., Thiokol Corp.

Bachman, Leigh M., B.S. in Ae.E., Asst. Engineer, Cylinder Development Group, Reaction Motors, Inc.

Bennett, R. H., M.S.Ae.E., Stress Analyst, Douglas Aircraft Co., Inc. (Santa Monica).

Bensen, Kenneth G., B.S.

Blue, William H., B.S. in A.E., Chief Computer & Student, University of Washington Aero. Lab.

Brooks, Doyle T., Jr., B.S. in Ae.E., Structural Design Engineer, Texas Engineering & Mfg. Co.

Brown, Kenneth, M.S., Lecturer in Dept. of Mechanical Engineering, University of Southern California.

Buecheler, George E., Jr., B.S.Ae.E., Stress Analyst "C," North American Aviation, Inc.

Burgess, Eldon S., Engineering Draftsman "B," Northrop Aircraft, Inc.

Carroll, George R., A.E., Coordinator, Stacy Bros. Gas Const. Co.

Cornish, Joseph J., III, B.S., Student, Louisiana State University.

Couturie, A. Delery, B.S. in M.E. (Aero.).

de Albuquerque, E. W. Saboya.

Detrick, Donald D., B.S.Ae.E., Draftsman, Boeing Airplane Co. (Wichita).

Edling, P. R., B.S., Instructor of Vocational Drafting, Victoria College.

Elwood, James J., Technical Writer "B," Consolidated Vultee Aircraft Corp. (Ft. Worth).

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Personnel Opportunities

This section is for the use of individual members of the Institute seeking new connections and organizations offering employment to Aeronautical specialists. Any member or organization may have requirements listed without charge by writing to the Secretary of the Institute.

Wanted

Flutter and Vibrations Engineer—Must have 4 years' experience in flutter and vibrations analysis of airplanes and airplane components; also must be capable of handling dynamic loads and aeroelasticity and should have some knowledge of electronics. Apply Curtiss-Wright Corporation, Technical Employment Office, 4300 E. Fifth Ave., Columbus 16, Ohio.

Preliminary Designers—With a minimum of 5 years' aircraft experience for design and analysis work in structures, thermodynamics, aerodynamics, and problems in power-plant and equipment installations. Inquiry should include comprehensive experience résumé. Address: Manager, Engineering Personnel, Bell Aircraft Corporation, P.O. Box 1, Buffalo 5, N.Y.

Design Engineers—Design engineers with 3 to 10 years' aircraft design experience needed to assist in design of high-performance military aircraft. Salary commensurate with training and experience. Chance Vought Aircraft, Dallas, Tex.

Design Engineers—For work on heavy-type bomber aircraft. Requires a B.S.E. and a minimum of 5 to 10 years' aircraft experience in wings, landing gear, controls, empennage, hydraulics, and body and electrical design. Please direct reply to Administrative Engineer, Boeing Airplane Company, Wichita Division, Wichita, Kan.

Research Positions—Open for physicists, mathematicians, and statisticians with the Naval Ordnance Test Station, Pasadena, Calif. Real opportunity is offered to high-caliber scientific personnel to work with top management in evaluation of weapons research and development. These are Civil Service positions GS-11 to GS-15 ($5,400 to $10,000). Reply with brief outline of education and experience to Personnel Department, Naval Ordnance Test Station, 3202 E. Foothill Blvd., Pasadena, Calif.

Preliminary Analysis and Design Engineers—Must have 3 to 10 years' aircraft experience with minimum of 2 years in aircraft or missile preliminary analysis and design. Advanced degrees and experience in supersonic design, configuration analysis, and economic evaluation are particularly desirable. **Aerodynamics Engineers**—To perform studies in supersonic aerodynamics on extensive guided-missile program. Positions open for men with training and experience in dynamic stability, performance, configuration development, aerothermodynamics, and flight testing. Salary dependent on qualifications. Address: Aerophysics & Atomic Energy Research Division, North American Aviation, Inc., 12214 Lakewood Blvd., Downey, Calif.

Research and Development—Electronics Engineers, Senior—Degree, plus 4–8 years' experience as Project Engineer in radar, design system, and circuit analysis. **Intermediate** ratings for Electronics Engineers with degree, plus 2–4 years' experience in circuit design, antenna and microwave design. **Electromechanical (Fire Control System)**—Degree with at least 4 years' experience in either servomechanisms, analog computers, or circuitry development. Must have academic training in mathematics. **Electromechanical Engineer in Flight Test, Senior**—Minimum of B.S. degree, but M.S. degree desired. At least 5 years' experience in instrumentation in research laboratory testing and devising new measurement systems. Will be responsible for technical integrity and further development of flight-test instrumentation. **Structures Engineer, Senior**—Engineering graduates with at least 3 years' experience in aircraft structural analysis techniques sufficient to adapt and modify equations and analysis methods to meet specific structural problems. Must have good knowledge of report-writing techniques. Those with at least 1½ years' experience will be considered for intermediate openings. **Aerodynamic Engineers, Senior**—Technical graduates with at least 4 years of proved experience in aerodynamics work in either performance, stability and control, air loads or flight-test reduction. Graduates with advanced degrees with thesis in aerodynamics or thermodynamics and at least 2 years' experience in aircraft will also be considered. **Heating and Ventilating Engineer in Aerodynamics, Senior**—Degree and 5 years' experience in aircraft cabin conditioning and anti-icing systems. Knowledge of heat transfer, thermodynamics, and gas dynamics. Familiar with design and installation of cabin conditioning equipment. **Propulsion Engineer, Senior**—Degree and 5 years' experience in air-frame or power-plant development and installation. Familiar with design and operation of power-plant components. Familiar with turboprop, jet, ram-jet. Background in thermodynamics, fluid dynamics, and gas dynamics. Must be analytical and capable of good analysis report writing. Send résumé to Employment Department, The Glenn L. Martin Company, Baltimore 3, Md.

Thermodynamicist—Graduate engineer to perform design analyses in one or more phases of aircraft power-plant installations, such as duct flow, heat transfer, cabin conditioning, or fuel system analysis. Minimum 2 years' experience. Apply Engineering Personnel Manager, Northrop Aircraft, Inc., Hawthorne, Calif.

Graduate Mechanical or Chemical Engineer—For design and analytical work. To do research on rocket engine components. Experience in combustion, thermodynamics, and heat transfer essential. Additional experience in hydraulics, machine design, and metallurgy desirable. Willingness and ability to use mathematical analysis and theoretical background required. Aerojet Engineering Corporation, P.O. Box 296, Azusa, Calif.

Graduate Mechanical or Chemical Development Test Engineer—To supervise test operations and rocket engine components. Experience in aircraft engine or allied test fields essential. Knowledge of, or experience in, instrumentation, hydraulics, and aircraft hydraulic systems desirable. Should have B.S. degree; advanced degree desirable. Must be willing to accept responsibility entailed in this type of test operation. Aerojet Engineering Corporation, P.O. Box 296, Azusa, Calif.

206. Aircraft Design Engineer—Graduate engineer with minimum of 10 years' aircraft experience in hydraulic systems for heavy aircraft. Design of good, practical aircraft components that may be required for proper installation of the units of hydraulic systems necessary. Particular experience in design or landing-gear components desirable. Give details of experience and past earnings in letter of application.

204. Assistant or Associate Professor of Aeronautical Engineering—To teach aircraft design and propulsion courses in the Aeronautical Engineering Department of a well-known eastern institution. Previous teaching experience and advanced degrees desirable. Service for 10-month academic year. Salary dependent upon qualifications. Inquiries should include summary of educational and industrial experience.

203. Chief Inspector—East coast helicopter manufacturer requires highly qualified inspector qualified to accept responsibility for administration and organization of inspection department, dealing with AN contracts. Excellent opportunity for right man. Give details in first letter.

202. Engineers—East coast helicopter manufacturer requires experienced personnel to permit rapid expansion of engineering department. Has immediate need for structural design engineers, mechanical design specialist, weight engineer, stress analysts, senior draftsmen. Minimum 5 years' experience. Knowledge of AN design standards desirable. Give details in first letter.

196. Engineers—Well-known aircraft company in Southern California now has attractive openings for Aerodynamicists, Hydrodynamicists, and Aero-Thermodynamicists. Candidates with supervisory potential, above average technical ability, and not less than 5 years' experience, preferably on flying boats, will be favorably considered. This is an ideal opportunity. Include in reply a complete description of your education, experience, ingenuity, and salary expected.

187. Part-Time Instructor—To teach basic aeronautical subjects in large southeastern engineering school. Ideal opportunity for graduate work in related fields. When applying send complete transcript of college credits.

180. Professor of Aeronautical Engineering—Qualified to teach fluid mechanics, gas dynamics, thermodynamics, and specializing in jet and rocket engines. Advanced degrees required. Salary open. Location Mid-West.

179. Professor of Aeronautical Engineering—To teach undergraduate aerodynamics, compressible fluids, performance, or stability courses. Some research facilities available. Advanced degrees required. Some graduate teaching. Salary open. Location Mid-West.

The number preceding the notices represents the Box Number of the Institute of the Aeronautical Sciences to which inquiries should be addressed.

Available

207. Aviation Executive—Ten years' experience covering sales and service representation, production management, and managing directorship with reliable firms in the aviation field. Extensive travel in Far East as consultant on airfreight operations and factory methods. Age 37. Location open. Further data on request.

205. Mechanical Engineer—Licensed Professional Engineer. Eleven years' experience; 2 years of teaching evening classes, Washington University, St. Louis, Mo. Supervisory experience includes 3 years as Chief of Design, 1 year as Project Engineer (power plant), 1 year as Group Engineer (power plant), 1 year as Lead Man (power plant and preliminary design). Active Wright Field and BuAer contacts 1943–

1945; active C.A.A. Washington contacts 1945–1946. Experienced in preliminary design (8 years), including practical estimations of manpower (shop and engineering) and material costs. Diversified experience ranges from complete airplane and guided-missile design to components, including liquid-oxygen test devices, injector plates, rocket-motor shells, high-speed bearing application, miniature power plants, and optics systems for seekers. Will consider supervisory or administrative work with a small, aggressive, and well-financed group. Currently holds two Professional (P-6) Civil Service Ratings.

200. Aircraft Equipment Sales Engineer—Engineering Degree. Six years of sales office management; 9 years of aircraft company design. Hydraulic, power-plant, and missile equipment manufacturers' type of work. Has handled liaison work with services. Air-frame service engineering. Willing to relocate. Desires sales or engineering coordination work with air-line, equipment, or air-frame company.

199. Instrument Department Head—Aircraft or industrial; Liberal Arts degree; aircraft instrument training course, Omaha University; instructor, electronics theory, U.S. Signal Corps. Instrument technician and instrument laboratory foreman; later flight-test and engineering tests of instrumentation for B-29 last 10 months of war. Foreman industrial instrument department, ordnance plant. A total of 8 years' instrument experience: 5, aircraft; 3, industrial, covering indicating, recording, and controlling instruments of pneumatic, electrical and electronic applications, and drafting, designing, engineering report writing. Member of The Instrument Society of America.

198. Aeronautical Engineer—Age 25. Graduate of the Academy of Aeronautics in Aircraft Design and Construction, August, 1949. One and one-half years' civilian and 3 years' military experience in aircraft and engine overhaul and maintenance. Background includes "E" license. Eight months with aircraft-engine manufacturer as balancer and spin tester of the J-47 jet turbine and shaft. Desires position as junior engineer in the East Coast area.

197. University Teaching—Wind-tunnel Operation—Wind-Tunnel Assistantship and M.S. in Aeronautics, CalTech. Ten years' experience all phases aerodynamics with several aircraft manufacturers. Specializing in wind-tunnel testing, including model design, testing and tunnel operation, analysis of results, and company representation. Position teaching and wind-tunnel operation desired.

195. Pilot-Aeronautical Engineer—B.S.-Aero.E., Aeronautical University of Chicago. Five years' general design experience; includes 1 year of specialization in guided-missile-design research and proposal work; consultant on two private aircraft research projects; 1 year of specialization in aircraft hydraulics systems design, installation, and actuator design; varied experience in building structures design and in architecture. Rated in U.S.A.F. (R.O.C.) as Engineering Design and Development Officer (MOS 7050). Has current multiengined (Land) commercial pilot license. Majority of time is in B-25 and P-38 type aircraft; currently active in Air National Guard flying C-47 type aircraft. Desires permanent position, with avenues for advancement, in missile-design research and development program or flight test with an established and progressive firm. Prefers Mid-West to Western United States or abroad.

194. Assistant Professor—Doctor's Degree in Mechanical Engineering. Seven years' teaching and research experience on undergraduate and graduate levels. Air Force Project Leader. Specialized in mathematical fluid mechanics and applied mechanics. Wants similar position with large university.

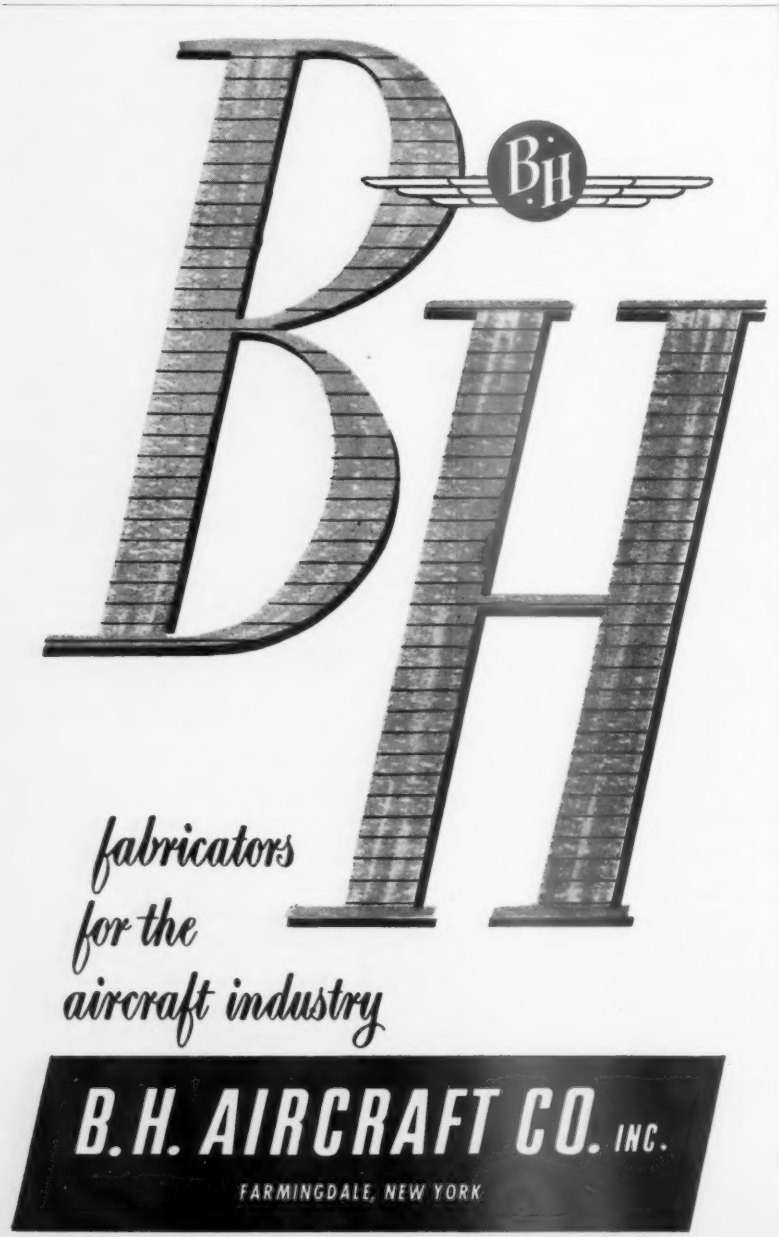
193. Aeronautical Engineer—Graduate of 2-year aeronautical engineering course with high average, October, 1949. Experience in aircraft-seat designing and building since graduation. Proficient draftsman. Familiar with all shop tools. Capable of assuming responsibility. Desires locating on East Coast. Interested in designing, particularly tool designing.

192. Engineering Executive—Widely experienced in industrial and Governmental organization and practice. Graduate engineer and commercial pilot. Work in private industry has included aircraft design, project engineer, engineering administration, engine sales and service, manufacturer's Washington representative. Military wartime assignments in responsible aviation engineering, material, and maintenance posts. Postwar supervision of research and development programs. Capable of taking full responsibility for projects or of working as member of team.

191. Aeronautical Engineer—B.S.Ae.E., Aeronautical University, 1950. Would like starting opportunity in design and research, preferably in the field of rocket and jet propulsion. Some machine-shop and aircraft sheet-metal experience. Good scholastic record. Willing to continue schooling. Age 26, location open.

190. Senior Aerodynamic Engineer—With excellent theoretical background and wide practical experience. Expert in stability and control, servomechanisms analysis, dynamic problems, air loads, and remote control. Familiar with all angles of modern aerodynamics, pilotless airplanes, etc. Desires work in research, development, or preliminary design.

188. Aerodynamicist—B.S. in Aero., B.S. in Math., M.S. in Aero. Desires responsible position with research or development organization in or near an educational institution where advanced studies in aerodynamics, mathematics, and physics could be pursued. Has extensive experience in all phases of subsonic, transonic, and supersonic wind-tunnel testing—i.e., design, operation, and data reduction. Good background in thermodynamics and propulsion. Is familiar with shop practices. One year's teaching experience on graduate level. Would consider teaching supplemented with research.



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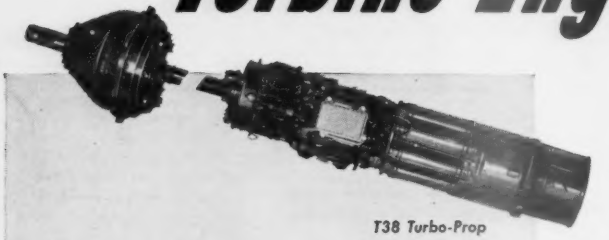

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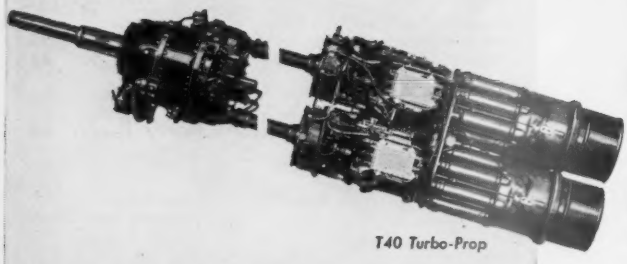

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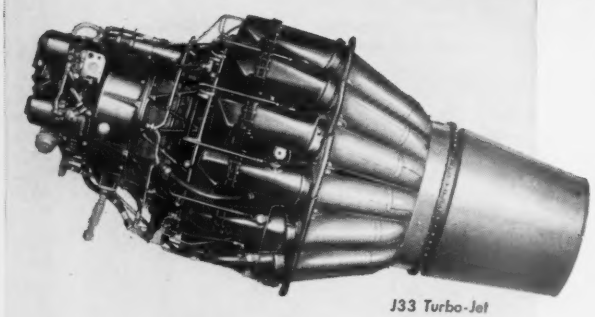

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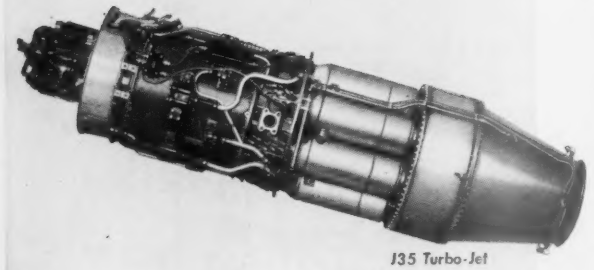

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